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A Geochemical Investigation of the Usakos Gem Tourmaline Pegmatite, Namibia

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A Geochemical Investigation of the Usakos Gem Tourmaline Pegmatite, Namibia

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Abstract

The Usakos pegmatite, Namibia, is a highly evolved, rare-element LCT-type pegmatite. The pegmatite is emplaced in metasedimentary rocks of the Kuiseb formation. Ca and Al enrichment at the contact, B mineralization in the country rock and Sr mineralization in the core of the pegmatite are all evidence of interaction of the pegmatite melt and hosting country rock. K/Rb ratios within mica and feldspar are very low indicating a highly evolved melt. Tourmaline has a fractionation trend from Fe-rich at contact and intermediate areas to Fe-depleted in core regions and pockets. Columbite tantalite group minerals show a similar trend in fractionation, with columbite-(Fe) found near the pegmatite country rock contact and tantalite-(Mn) found in the core region. Trace element geochemistry from samples of pegmatite-country rock contact is enriched in light rare earth elements. Whole rock geochemistry provides evidence of the geochemically evolved nature of the pegmatite forming melt.

Keywords: Pegmatite, Geochemistry, Usakos, Petrology, Tourmaline

Introduction

The study of pegmatites is both scientifically and economically valuable. In the scientific community, pegmatites have generated many debates. The most engaging of these are centered on their classification and genesis. Economically, the most important pegmatites belong to the rare-element class. Pegmatites belonging to this class are typically enriched in incompatible elements (high-field strength and large ion lithophile elements), and a variety of these elements comprise metal ores of economic importance (Linnen 2012). In addition to strategic metals, pegmatites are a source for some of the finest, most spectacular gem stones ever produced (Simmons *et al.* 2003).

Simmons *et.al.* (2003) provides a comprehensive review of the most current and generally accepted model for the formation of pegmatites. Most pegmatites are granitic in composition, with additional quantities of volatiles, rare-earth, and trace elements comprising approximately 1 wt. % of the melt. During formation, granitic magmas undergo *fractional crystallization* in which the melt becomes increasingly enriched in volatiles, fluxes, and incompatible elements. Due to the size and/or valence of volatiles, trace, and rare-earth elements, they are excluded from the common rock-forming minerals and remain in the melt. As this process continues, the melt becomes increasingly enriched in these elements. Magma of the enriched composition, which is now less dense than the parent magma, will normally escape into the surrounding country rock to form pegmatites around and further away from the

parent magma. Pegmatites that are more enriched in volatiles and fluxes are typically located a farther distance from the parental magma.

Černý's (2012) classification of pegmatites is the most updated version accepted for pegmatite classification (Černý, 2012 Table 1).The classification scheme, a revision of Černý's (1991a) pegmatite classification, categorizes pegmatites according to minor element content. The categories are Abyssal, Muscovite, Muscovite - Rare-Element, Rare Element, and Miarolitic. The Rare-Element class is further divided based on elemental assemblages into NYF-type (niobium, yttrium, and fluorine) and LCT-type (lithium, cesium, and tantalum).

Most pegmatites occur in groups or swarms within a metamorphic host rock and may be related to a nearby batholith or large pluton of granitic rock (Simmons et.al. 2003). Černý (1991b) discusses rare-element pegmatite populations on a regional scale with respect to a parental granite. Černý proposed that the proximity of any pegmatite type from its source is proportional to the thermal stability of its particular melt composition. He states this as the dominant reason for a regional chemical zoning of pegmatite groups relative to their parental pluton. While this type of zoning is common in pegmatite fields, it is not always observed. For example, the distribution of granitic rocks and pegmatites of the Oxford pegmatite field (Maine) around the Sebago pluton does not exhibit the regional chemical zonation described by Černý (Simmons et.al. 2003). Furthermore, there are cases in which pegmatite fields cannot be chemically related to a parental granite, such as the Hoskin Lake pegmatites of Florence Co., Wisconsin (Falster, 2011).

Class	Subclass	Type	Subtype	Family
Abyssal	HREE LREE U			NYF
	B Be			LCT
Muscovite				
Muscovite– Rare Element[1]	REE			NYF
	Li			LCT
Rare Element	REE	allanite–monazite euxenite gadolinite		NYF
	Li	beryl	beryl–columbite beryl–columbite–phosphate	LCT
		complex	spodumene petalite lepidolite elbaite amblygonite	
		albite–spodumene albite		
Miarolitic	REE	topaz–beryl gadolinite–fergusonite		NYF
	Li	beryl–topaz lepidolite		LCT

Table 1 - Černý (2012) Classification of pegmatites. The Usakos pegmatite classification is highlighted in gray.

The Usakos pegmatite is an economically significant pegmatite that was originally mined for tin and is currently producing spectacular gem quality tourmaline. The pegmatite is classified as a Lepidolite Subtype Rare-Element pegmatite based on the classification scheme of Černý (2012) (Table 1). Scientifically, this pegmatite poses some interesting problems. In a regional study of the Usakos pegmatite field, the pegmatites are described as exhibiting varied chemical signatures with random spatial relationships (Owen, 2010). Furthermore, some of the

less economically important pegmatites can be linked to surrounding granites, but in some instances more economically viable pegmatites are unable to be related to parental granite bodies (Keller and Von Knorring, 1989).

This study offers the first thorough mineralogical and geochemical investigation of an economically important pegmatite belonging to the Usakos – Karibib pegmatite belt. The purpose of this study is to describe the geochemistry of tourmaline, mica, feldspar, and other accessory minerals as they relate to the degree of fractionation and the petrogenic evolution of the pegmatite.

Regional Geological Setting

Damaran Orogen

Following the break-up of the supercontinent Rodinia, the Damaran Orogen in modern day Namibia resulted from suturing of the Congo and Kalahari cratons during the late Proterozoic and early Phanerozoic amalgamation of Gondwana (Prave 1996, Gray *et al.* 2008). The Damaran Orogen is comprised of three collisional belts, including the Damara belt, the Gariep belt, and the Kaoko belt. The Gariep and the Kaoko belts, trend N-S, and are parallel and proximal to the Namibian Atlantic coast. The Damara belt is described as the SW-NE trending inland branch of the Damara Orogen (Miller 1983).

The intra-continental Damara belt geographically represents an area 400 km wide and over 1000 km long. Within its lithological record, a complete Wilson cycle of rifting, marine transgression, convergence and final collision is present (Martin 1977, Jacob 1978, Miller 1983, Schneider 2004, Gray 2006). Based on lithologies, structure, deformation, metamorphic grade, magmatism and geochronology, the Damara belt has been subdivided into the following eight distinct tectonostratigraphic units: Northern Platform (NP), Northern Zone (NZ), Northern Central Zone (NCZ), Southern Central Zone (SCZ) Okahandja Lineament Zone (OLZ), Southern Zone (SZ), Southern Marginal Zone (SMZ), and the Southern Foreland (SF) (Miller 1983) (Fig. 2).

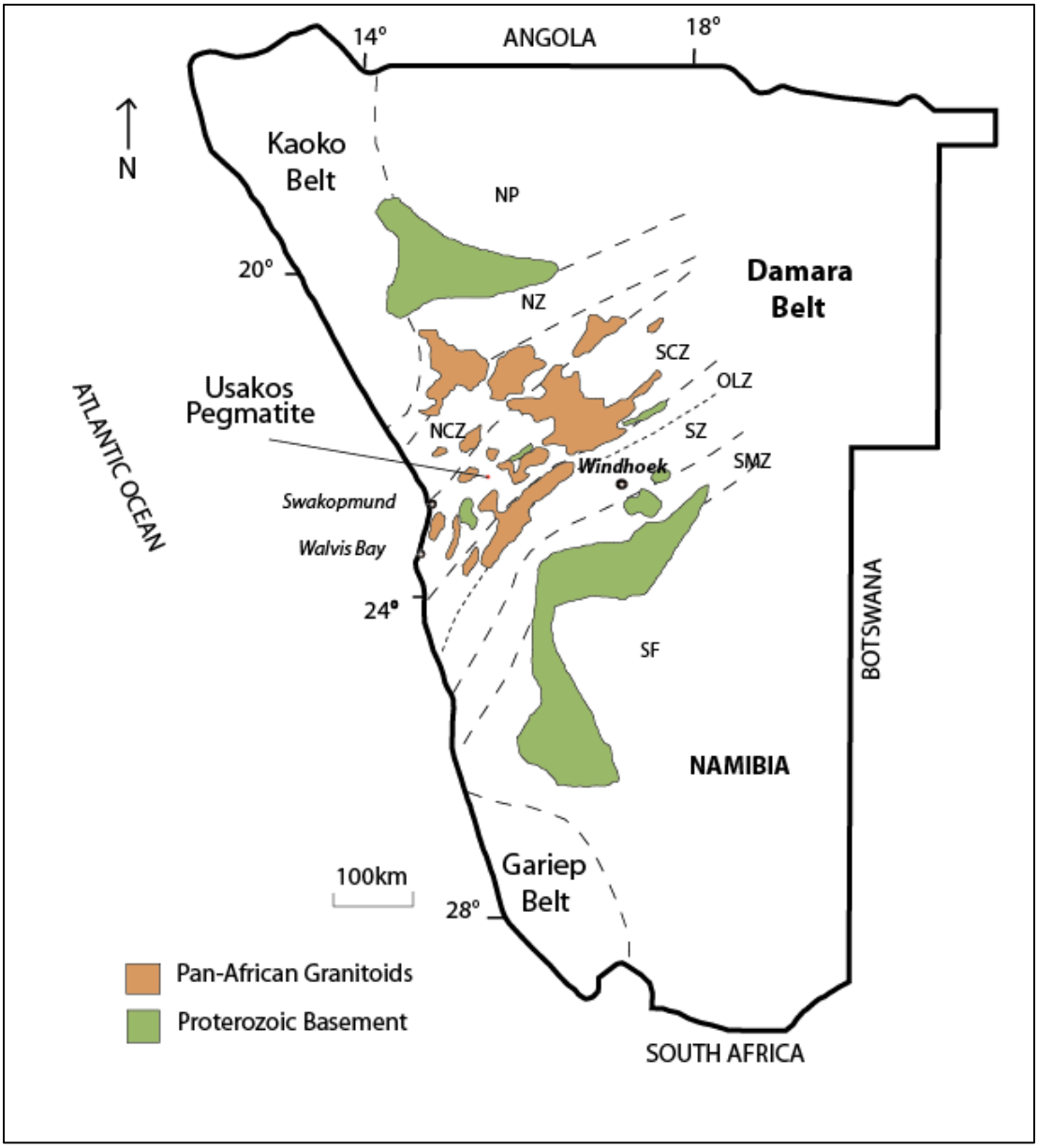


Figure 1: Tectonostratigraphic units of the Damara Orogen: Northern Platform (NP), Northern Zone (NZ), Northern Central Zone (NCZ), Southern Central Zone (SCZ) Okahandja Lineament Zone (OLZ), Southern Zone (SZ), Southern Marginal Zone (SMZ), and the Southern Foreland (SF) (Modified from Miller 1983, Kitt 2006).

The central zone of the Damara belt is characterized as the high temperature – low pressure zone and is sub-divided into the NCZ and the SCZ. The entire CZ of the Damara belt is host to abundant granitic plutons (Schneider 2004). The emplacement of the granitic plutons is related to the late- and post- tectonic evolution of the Damara belt ca 510-465 mya (Miller 1983, Jung *et al.* 2000, Owen 2011). In addition to granitic plutons, the CZ is host to a variety of pegmatite occurrences which are stratigraphically the highest intrusions in the CZ (Owen 2011). The Usakos pegmatite is located within the SCZ of the Damara belt (Fig. 1).

Pegmatites of the Karibib-Usakos Region

The Karibib-Usakos region is situated in the SCZ of the Damaran belt and has long been known to host a range of pegmatite occurrences (Wagner 1916, Cameron 1955, Keller & Von Knorring 1989). The pegmatites range from economically important pegmatites mined for Sn, Li, Nb, Ta, Cs, mica, feldspar, gem tourmaline and gem beryl; to simple pegmatites composed of microcline, microcline perthite, quartz, and albite with some pegmatites containing locally large quantities of muscovite, schorl, and/or almandine (Keller 1991, Keller et al. 1999, Roda et al. 2007).

The pegmatites of the Karibib-Usakos region are hosted by igneous and metamorphic rocks of the Damara sequence. In most cases the pegmatites lacking economic value, are related to either syn-tectonic Salem type granites or post-tectonic Donkerhoek granites. Few of the economic pegmatites are situated within a parent granite. The vast majority have intruded into the mica schist of the Kuiseb Formation, dolomitic marbles of the Karibib Formation, or quartzites of the Nosib Formation (Roda et al. 2007). These economic pegmatites are unmetamorphosed, post tectonic, and in most cases are unable to be linked to post tectonic granites (Keller & Von Knorring 1989).

The SCZ pegmatites have been studied on the basis of certain elemental or mineral occurrence spread throughout a specific pegmatite belt (Keller & Von Knorring 1989, Keller 1991, Keller et al. 1999, Roda et al. 2007). The pegmatite belts from these studies are defined in the map shown in Figure 2: The Northern Tin Belt (Ia: Strathmore pegmatite swarm; Ib: Karlowa pegmatite swarm; Ic: Uis pegmatite swarm); II: Central Tin Belt; IIIa: Rossing pegmatite belt; IIIb: Southern Tin Belt; IV: Karibib pegmatite belt; V: Okahandja pegmatite belt. The Usakos pegmatite is located close to the border but outside the perimeter of the Karibib pegmatite belt (Fig. 2).

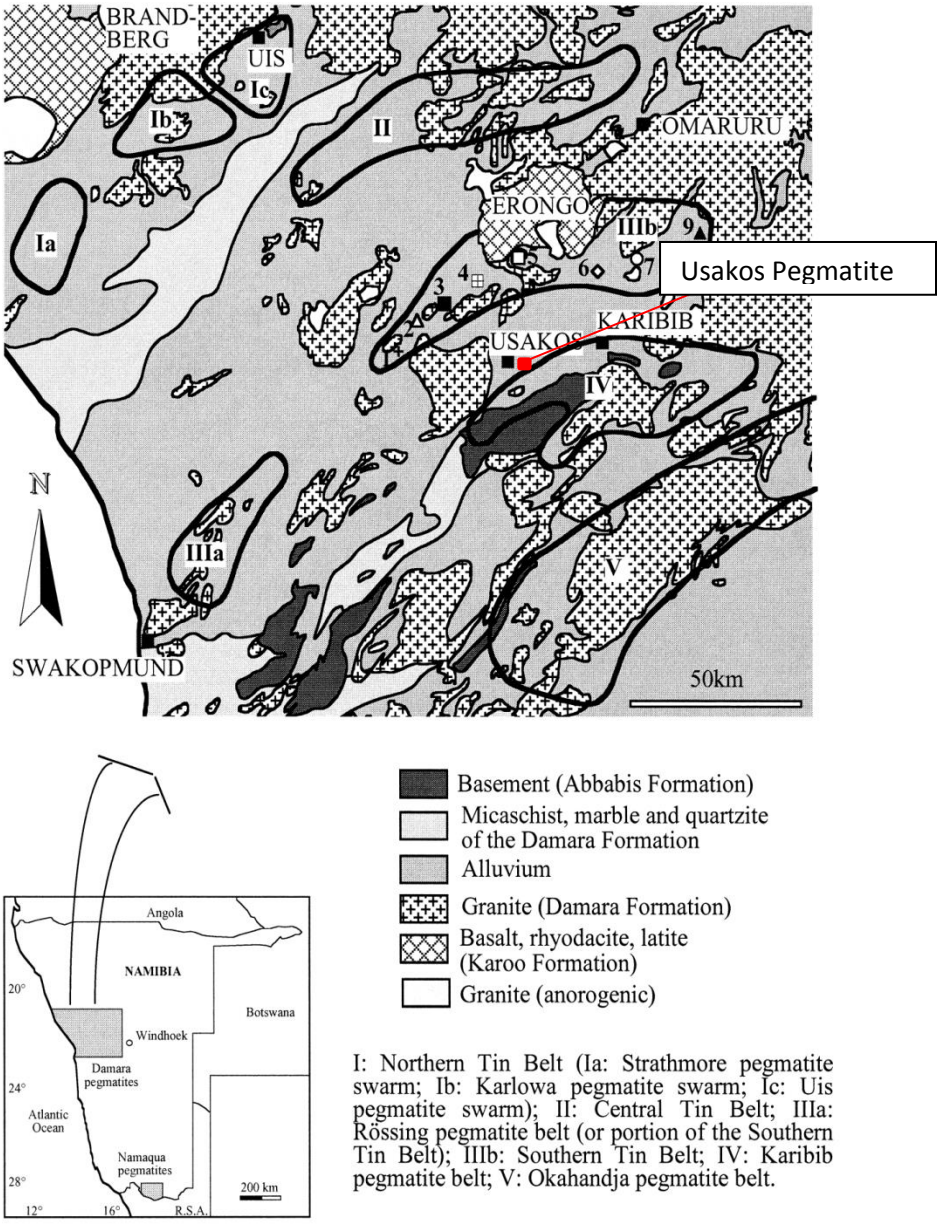


Figure 2: West Central Namibia pegmatite belts defined by Keller (1991)

Usakos Pegmatite Location and Description

The Usakos pegmatite is located approximately 3.30 km east of the town of Usakos, in the Erongo region of west central Namibia (Fig. 3). The pegmatite is emplaced in the muscovite bearing, quartz biotite schist of the Kuiseb formation and is associated with the Kranzberg syncline. The Usakos pegmatites surface exposure is a large flattened pod-like structure encompassing approximately 150 m by 90 m. The footwall contact is not exposed, making it difficult to determine the exact thickness of the pegmatite body. In some areas, the pegmatite wall is over 13 m from the basal exposure to the hanging wall contact.

The pegmatite lacks any obvious zoning as is seen in some large LCT-type pegmatites (Llorens and Mora 2010). However, there are areas of mineralogical heterogeneity present in the pegmatite body, such as, splays of tourmaline crystallization and pods of phosphate mineralization (Fig. 4a & 4b). In addition, the pegmatite is pocket bearing, and known to produce gem-quality tourmaline (Fig. 4c).

Google earth image of the Usakos Pegmatite, West Central Namibia, Africa

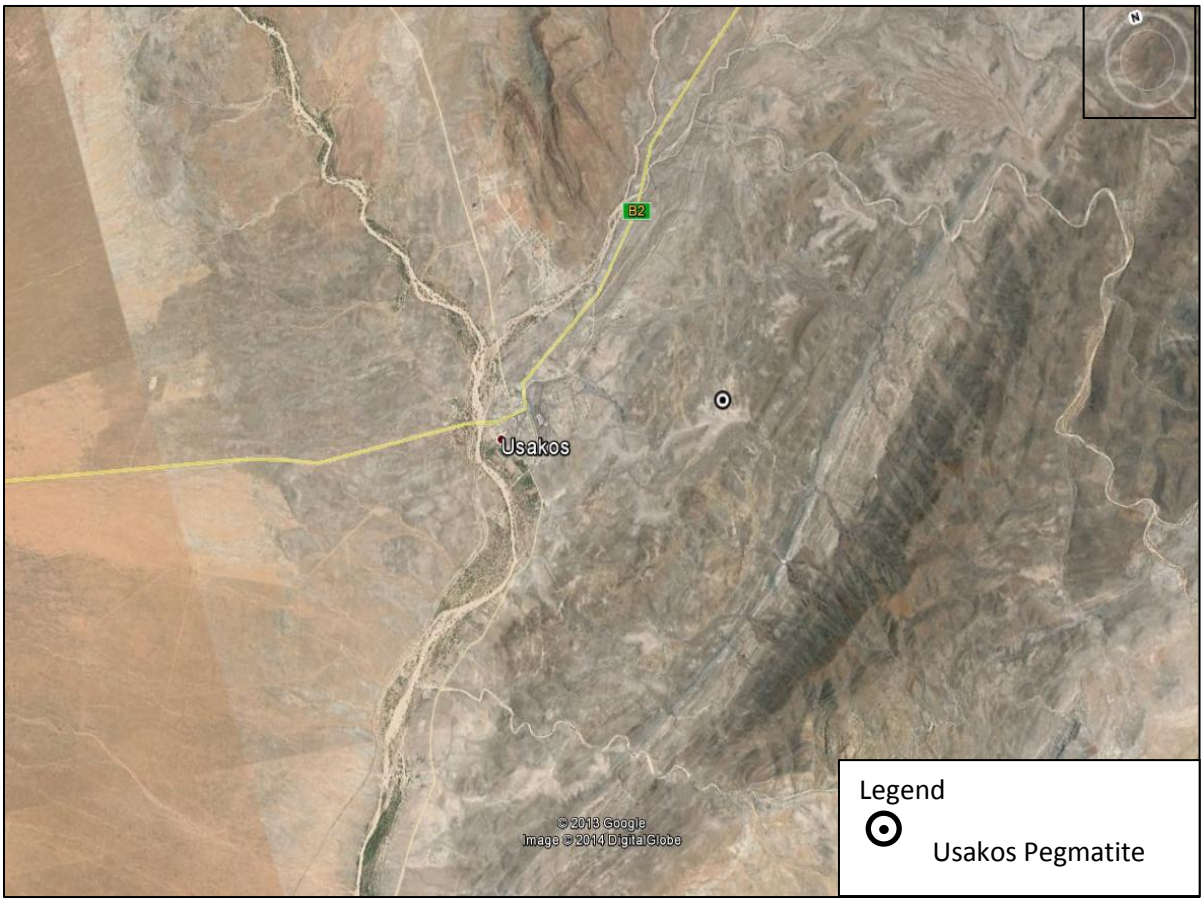


Figure 3: Google Earth imagery of the Usakos pegmatite

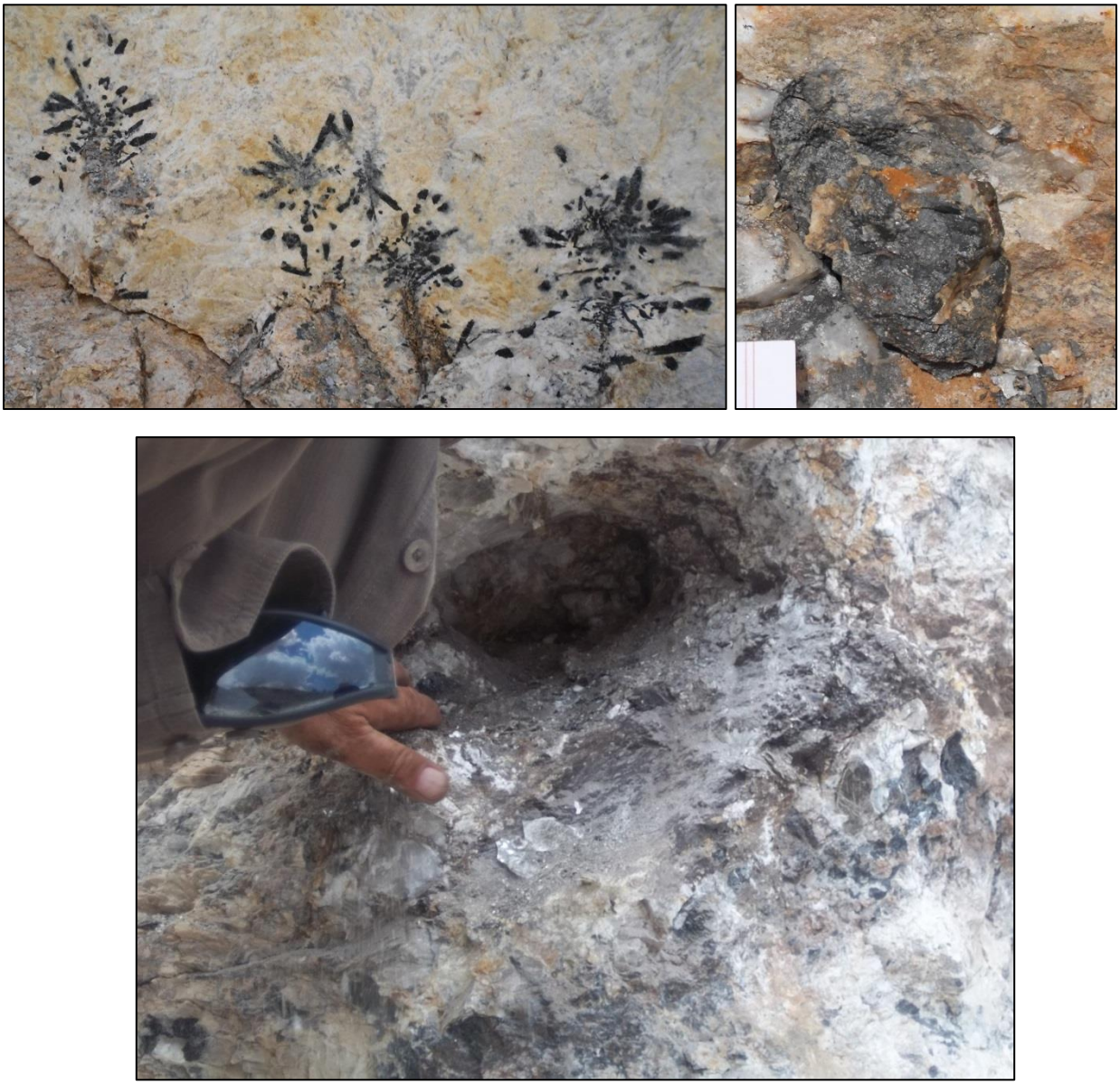


Figure 4: A. large tourmaline splays. Each cluster approx. 27 cm across.

B. phosphate pod. 4 cm x 9 cm x 3 cm C. Usakos pegmatite pocket.

Methods

Data Collection and Analytical Methods

Field sampling of the Usakos pegmatite, Namibia was conducted in January, 2013 by the University of New Orleans MP^2 research group. Samples were gathered at the pegmatite-country rock contact, areas in and around pockets, and from a transect from the pegmatite-country rock contact through to the base of the pegmatite exposure (Fig. 5). When available each sample contained the common rock forming minerals mica and feldspar. In addition, special care was taken to collect tourmaline from all sample areas when available. Furthermore, a suite of colored tourmaline was obtained from the mine owner. Before each sample was removed it was photographed with a scale and after removal each sample was catalogued and stored for transport back to the laboratory.

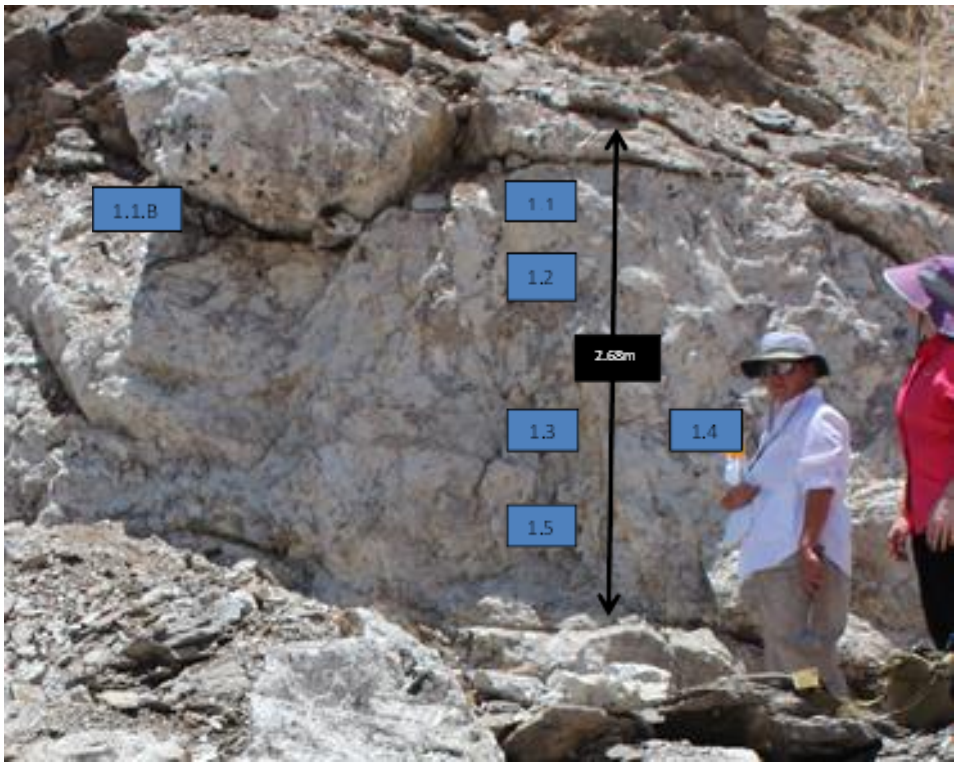


Figure 5: Usakos field team Kimberly Clark (left) Kristen Camp (right). Sample locations of pegmatite transect.

Thin Sections

Thin sections were completed by Applied Petrographic Services Inc. Samples were prepared for thin sections by cutting them into 27x46 mm rectangles using a diamond blade saw. Once prepared samples were sent to Applied Petrographic Services Inc., there the samples were mounted on glass slides and ground to a uniform 30 microns thin. Thin sections were analyzed using a petrographic microscope, to identify minerals, determine the presence of any textures, and complete modal analysis via point count method.

Heavy Mineral Separation

In order to separate heavy minerals from samples, a fist size portion of each sample was removed and crushed using a rock hammer. The portion was then placed in a SPEX 4200 Jaw Crusher to reduce the pieces to less than 6 mm. The crushed rock was then sieved through a 1 mm mesh, grains less than 1 mm were collected in plastic vials. The samples were then washed to remove any silt and then dried. Once dry, the grains were gravity separated using lithium metatungstate liquid adjusted to a density of 2.95 g/cm3. This method forces minerals with a density higher than 2.95 g/cm3 to settle at the bottom of the vial and minerals with a density less than 2.95 g/cm3 to remain on top of the liquid. The heavy minerals sequestered at the bottom of the vial were frozen in place using liquid nitrogen and the rest of the mixture was discarded. After thawing and rinsing the heavy mineral separates, they were mounted and identified using a scanning electron microscope.

Inductive Coupled Plasma Spectrophotometry

A selection of samples that are as representative as possible of the entire pegmatite were be analyzed using Inductively Coupled Plasma (ICP)-OES-MS. This technique identifies major and minor trace elements present in the sample. ICP-OES -MS ionizes the sample with inductively coupled plasma and then using a mass spectrometer to separate and measure those ions. To prepare samples for this technique the rocks were encased in a protective layer of thick paper to avoid contamination while being crushed with a rock hammer. After the rocks were broken to a suitable size they were placed in a ceramic vessel; this vessel was then placed into an 8510 Shatter Box. The Shatter Box was run for 100 minutes, milling the rocks into a fine powder ready for ICP-OES-MS analysis. The data collected from the ICP-OES-MS technique will be used for tectonic discrimination of the granite.

It is important to note that gathering samples which are representative of the entire pegmatites' chemistry for whole rock data is not practical. This is in part due to the large to gigantic grain sizes that by definition comprise a pegmatite. However, there is evidence that the wall zone will retain a resemblance of the geochemical signature of the parent granite due to the relatively small amount of flux present which would sequester REE and other incompatible elements in the melt (Simmons et. al. 2012). It is documented that wall zones of NYF-type pegmatites tend to be more representative of whole rock trace element chemistry than the wall zone of LCT-type pegmatites, but in any case it is the best representation available of the whole rock trace element chemistry obtainable (Simmons et. al. 2012).

Scanning Electron Microscope

An AMRAY 1820 scanning electron microscope with a KEVEX energy dispersive X-ray detector was used for preliminary identification and examination of all minerals (Fig. 6). To prepare samples for analysis via the SEM individual grains were manually separated from crushed rock under a microscope at 10x magnification. Each grain was then mounted in epoxy, ground flat, and polished using successively finer grit (from 1 to .05 microns). The samples were then cleaned in an ultrasonic cleaner, dried and coated with 250 Ångstroms of carbon under a vacuum with 1x10-5 torr. After which and EDS spectra and backscattered image was obtained for each grain. In addition, this machine was used to gather elemental maps from samples with rimed or inter-grown textures to identify chemical patterns.

Figure 6: Scanning Electron Microscope was utilized for identification, imaging, and acquisition of elemental maps of samples.

Electron Microprobe

After initial identification was completed using the SEM, the samples were analyzed using an automated, nine-spectrometer ARL SEMQ Electron Microprobe (EMP) to determine major and minor elemental weight percent (Fig. 7). Micas, feldspars, tourmaline, garnet, apatite, Nb-Ta oxides, zircon, montebrasite-amblygonite, cassiterite, and goyazite were all analyzed using the EMP. For the processes of sample preparation please refer to scanning electron microscope section. All analyses that were conducted via electron microprobe and standards used are presented in Appendix A.

Figure 7: Electron Microprobe was used for major and minor element analysis.

Direct Coupled Plasma Spectrophotometry

Elements lighter than flourine such as lithium, beryllium and boron are undetectable using the electron microprobe. To gather data on these elements we utilized a Direct Coupled Plasma Spectrophotometry (DCP) (Fig. 8). To prepare samples for DCP analysis 200 mg of each sample was separated under a binocular microscope and dissolved in 10 ml of 51% hydrofluoric acid at room temperature. This method was used to determine Li and Be content in the mica samples.

Figure 8: Direct-Coupled Plasma Spectrophotometer (DCP) used for trace element analyses.

Petrology

Thin sections were made of 10 samples from the Usakos pegmatite. The samples are representative of all areas that were sampled: the pegmatite-country rock contact, intermediate areas, the core region of the pegmatite and the country rock. Thin sections were analyzed using a petrographic microscope. The findings are presented in this section with all of the images presented in both plane polarized light and cross polarized light.

Petrographic Descriptions

Country Rock

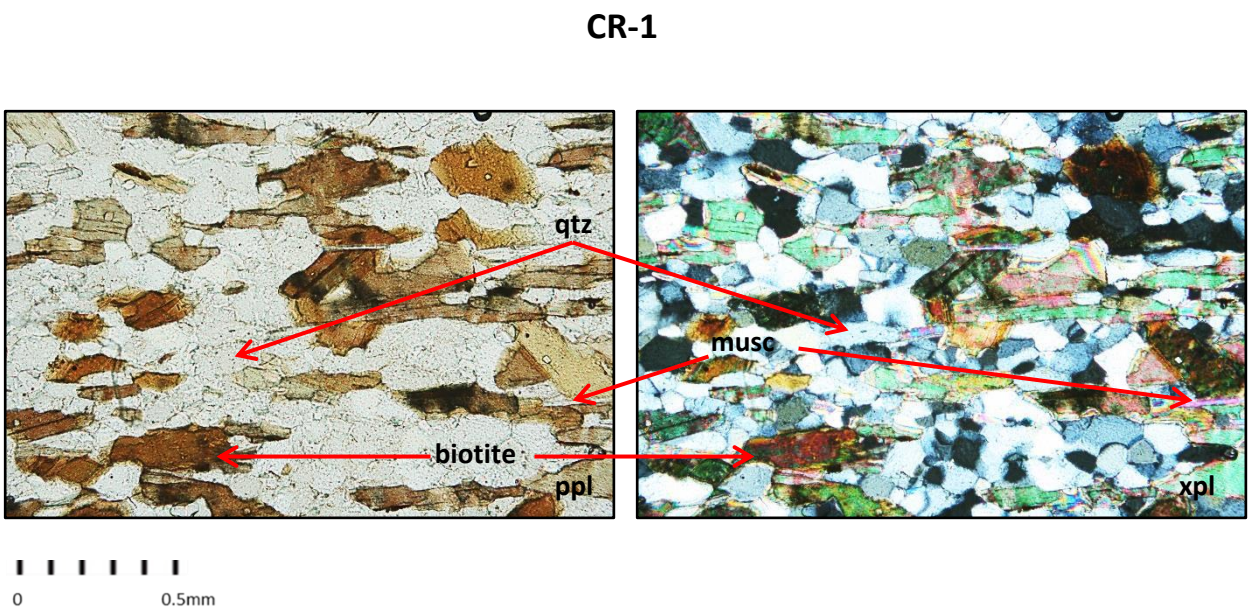


Figure 9: Thin section photomicrograph of sample CR-1

Sample Cr-1 was collected from the country rock that hosts the Usakos pegmatite. The sample was collected from within 25 cm of the pegmatite –country rock contact. CR-1 consists primarily of quartz and biotite with some minor muscovite. The country rock belongs to the Kuiseb formation.

Pegmatite-Country Rock Contact

CZ-1-A

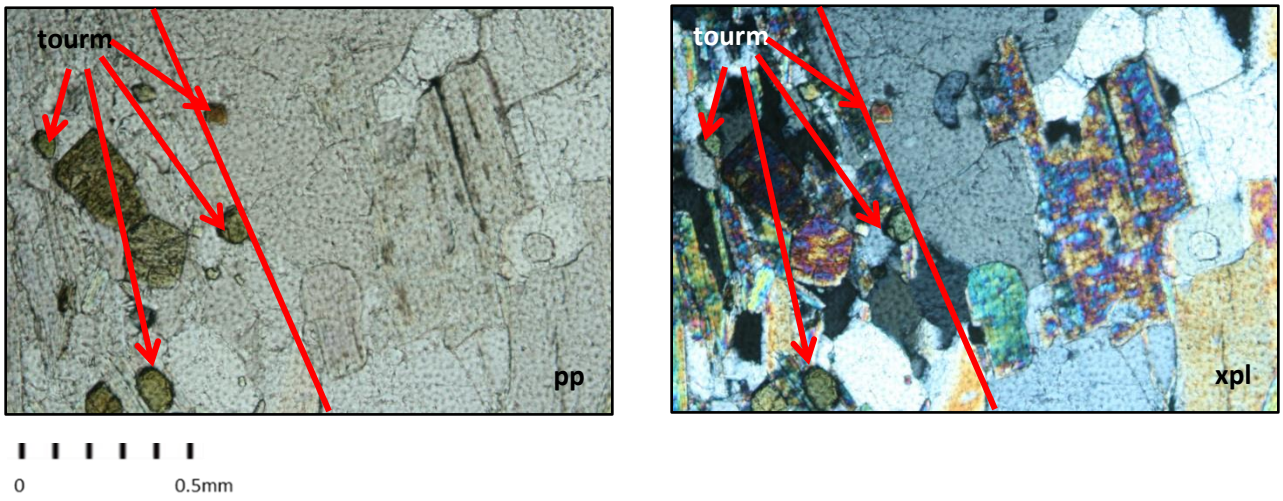


Figure 10: Thin section photomicrograph of sample CZ-1-A

Sample CZ-1-A was taken from the pegmatite-country rock contact. There is a distinct change from fine-grained country rock to the coarse-grained pegmatite. The red line denotes the contact between the pegmatite and the country rock. There is also evidence for some interaction between the country rock and the pegmatite in this sample. Sample Cr-1, taken from 25 cm away from the contact, contained no tourmaline. In this sample there is abundant tourmaline both the country rock and in the pegmatite. This is indicative that metasomatic exomorphism between the B-rich pegmatite melt and the country rock has occurred.

U-5

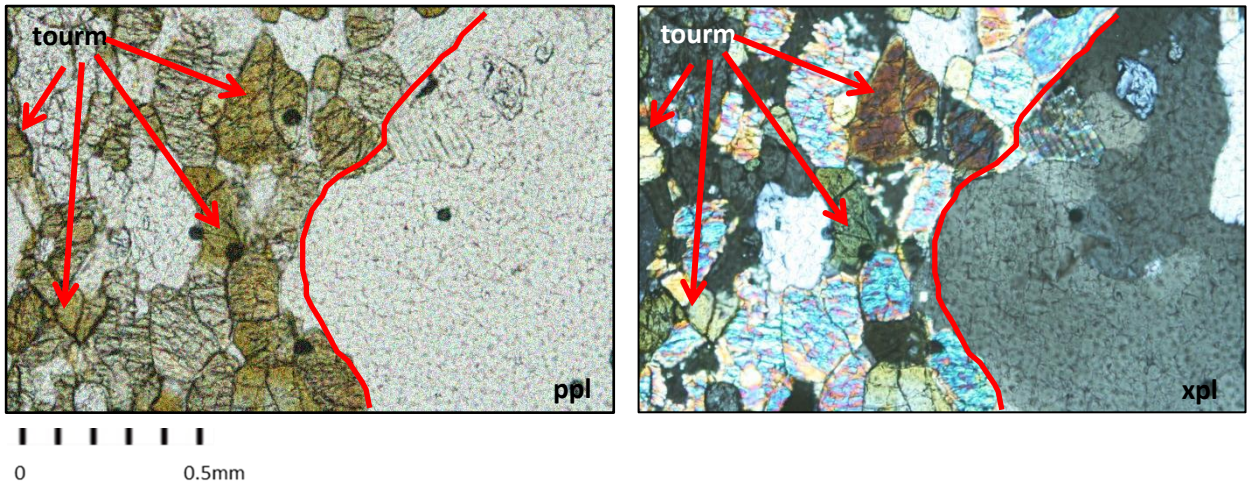


Figure 11: Thin section photomicrograph of sample U-5

Sample U-5 was a cactolith of pegmatitic melt that intruded a fracture within the country rock. In this thin section there is country rock present on either side of the pegmatite dike. In this image one side of the contact is shown. As in sample CZ-1-A there are tourmaline grains present in the country rock which show evidence for interaction between the country rock and the pegmatite. In addition there is more muscovite present in this country rock than in the country rock sample from farther away from the pegmatite-country rock contact. The red line denotes the change from the fine-grained country rock to the coarse-grained pegmatite.

Intermediate

1.1

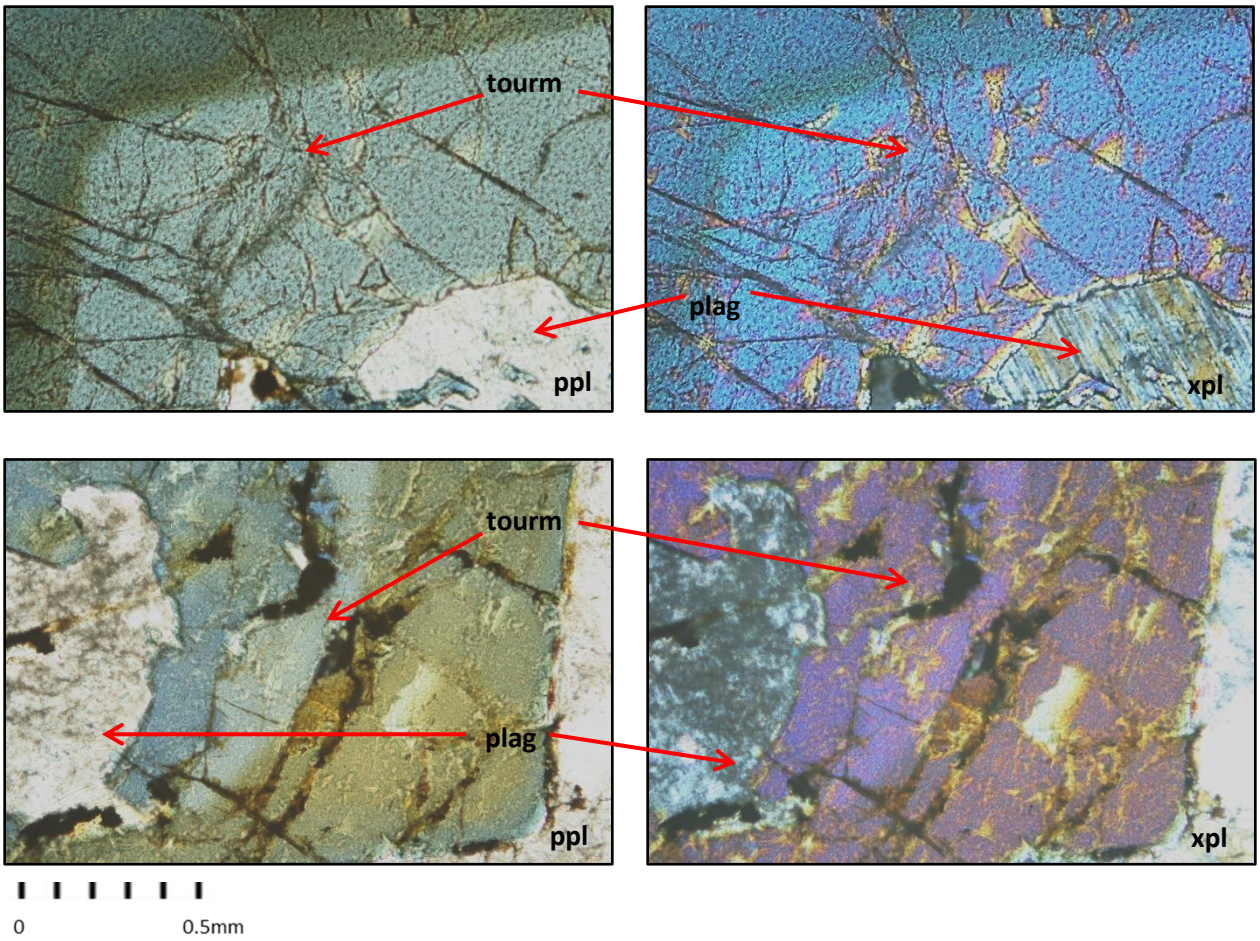


Figure 12: Thin section photomicrographs of sample 1.1

A transect through one of the exposed walls of the pegmatite was sampled; sample 1.1 was the first from that group. It was the closest of that group to the country rock but well within the limits of the pegmatite (48.26 cm from contact). The sample consists of plagioclase, quartz and tourmaline with minor amounts of muscovite present. One of the tourmaline crystals present in this sample is described as a shelled tourmaline and distinct color zoning is visible. The grain has an interior of plagioclase. In the image above both ends of the crystal are displayed.

1.1-B

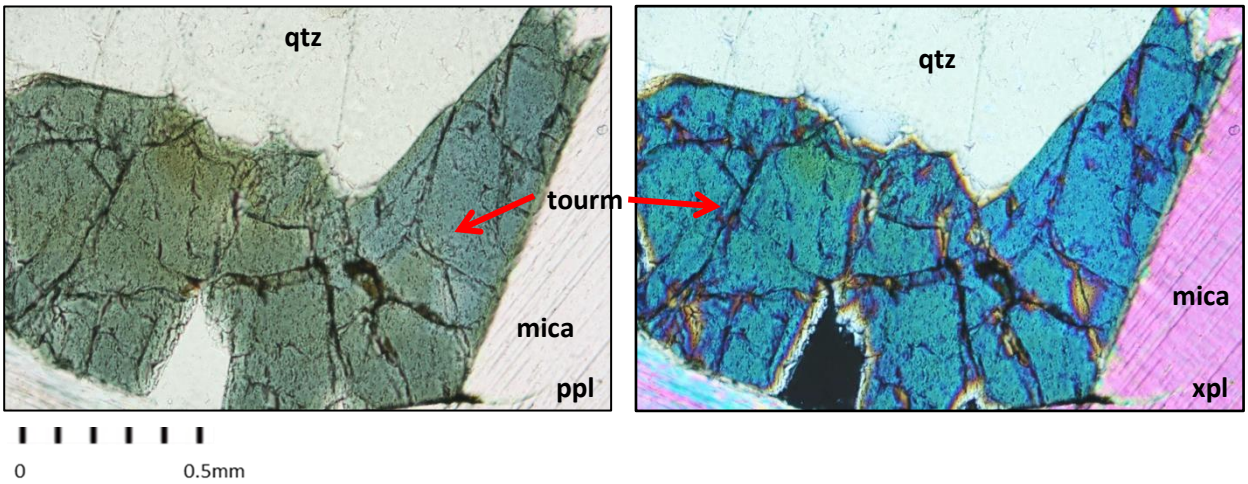


Figure 13: Thin section photomicrograph of sample 1.1-B

Sample 1.1-B was also collected along the transect of the exposed pegmatite wall. Large grains of tourmaline over 1.5 mm wide were present in this sample.

1.3

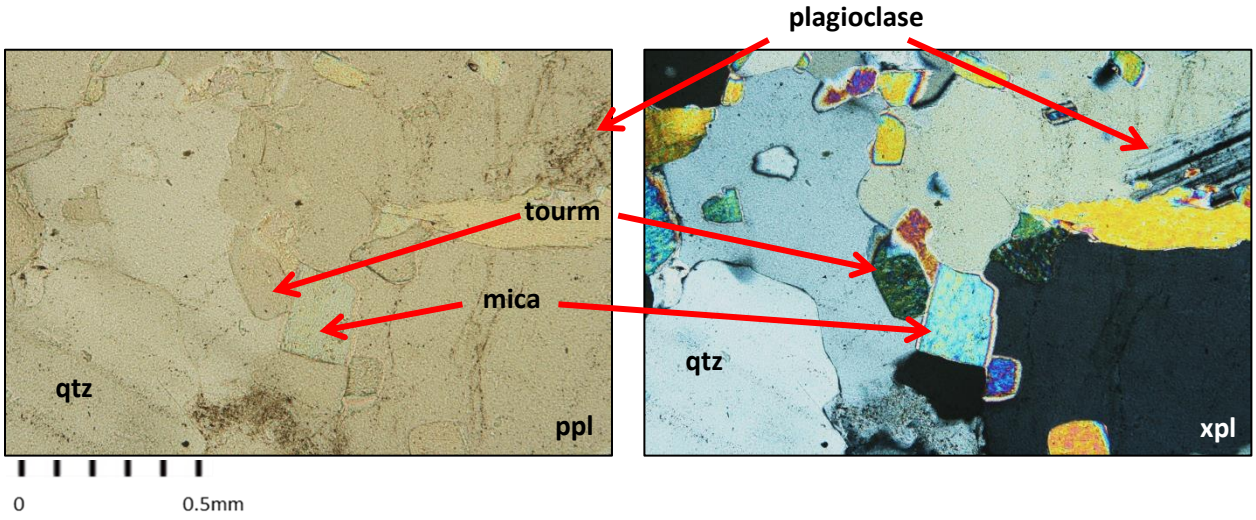


Figure 14: Thin section photomicrograph of sample 1.3

Sample 1.3 was taken along the transect of the pegmatite 1.54 m from the country rock contact. The sample is relatively more fine grained than most other samples from the transect. Quartz, plagioclase, tourmaline, and muscovite were identified. Tourmaline is subhedral with an average diameter of .2 mm. Muscovite crystals range in grain size from .1mm to 1.5mm in diameter.

1.6

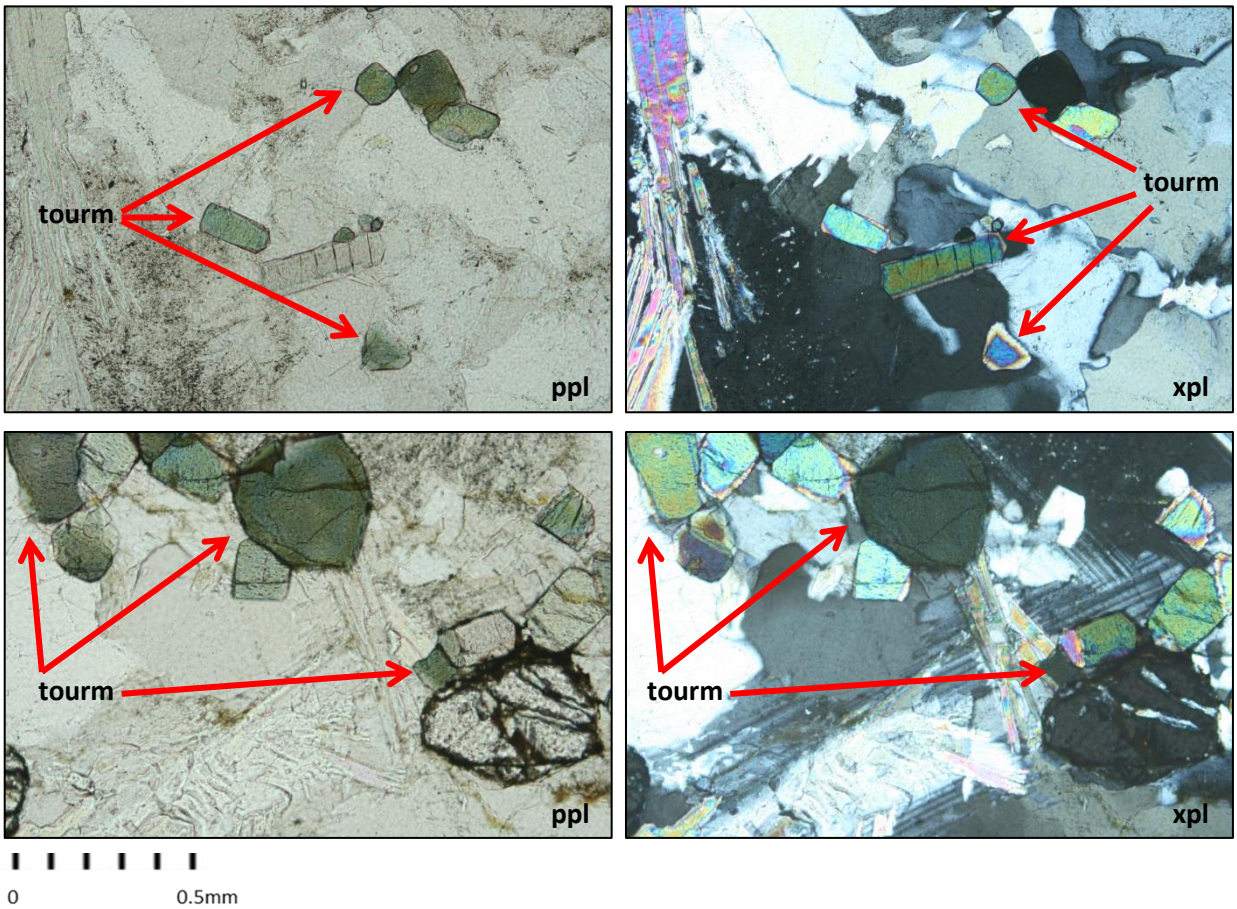


Figure 15: Thin section photomicrograph of sample 1.6

Sample 1.6 is from a boulder that was interpreted to be close to in situ in the intermediate area of the pegmatite but had recently been removed from the pegmatite. This sample is porphyritic with abundant tourmaline with quartz, muscovite, and plagioclase.

1.7

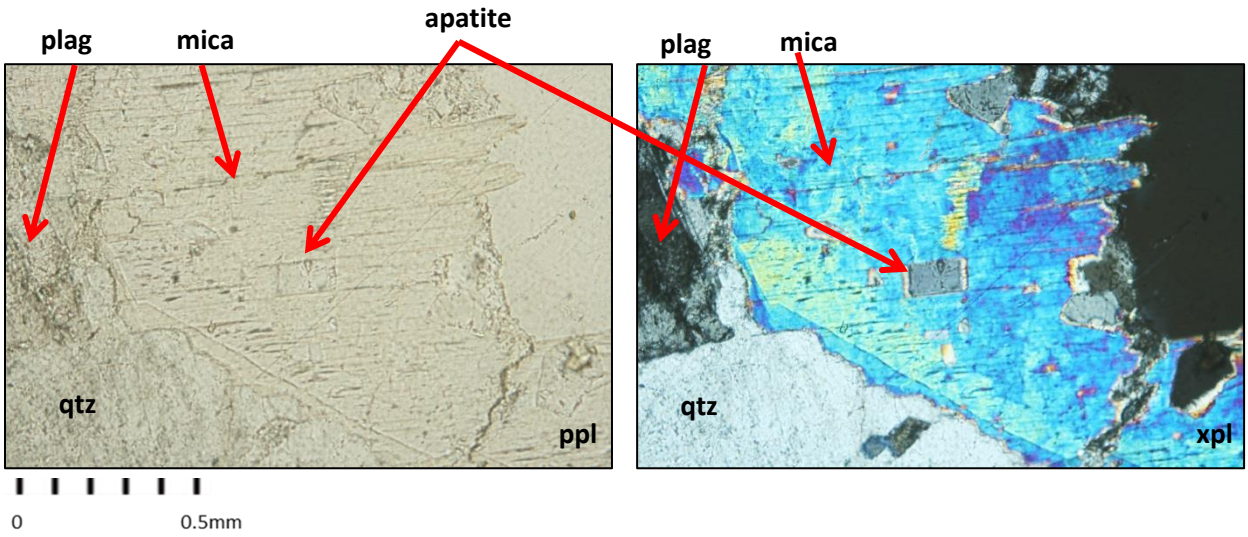


Figure 16: Thin section photomicrograph of sample 1.7

Sample 1.7 was taken from the transect of the pegmatite wall. The thin section is comprised predominately of quartz, and plagioclase, and muscovite with minor tourmaline, and apatite. All the mineral phases are subhedral with grain sizes ranging from .2 mm to over 1 cm.

Core Region

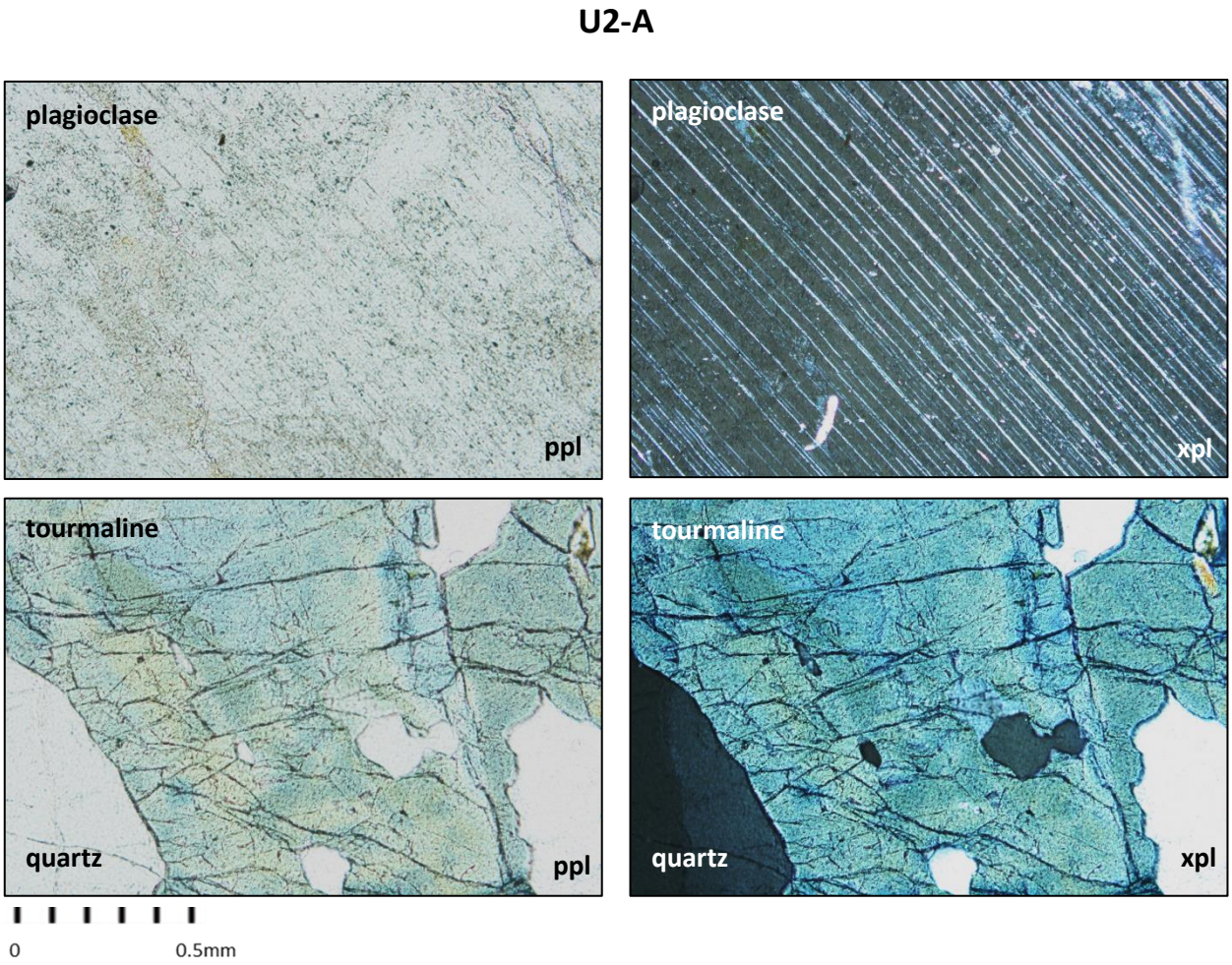


Figure 17: Thin section photomicrograph of sample U2-A

Sample U2-A was collected near a pocket. There is a marked increase in the grain size in this sample from other samples; with grains in excess of 4 mm. The plagioclase exhibits polysynthetic twinning.

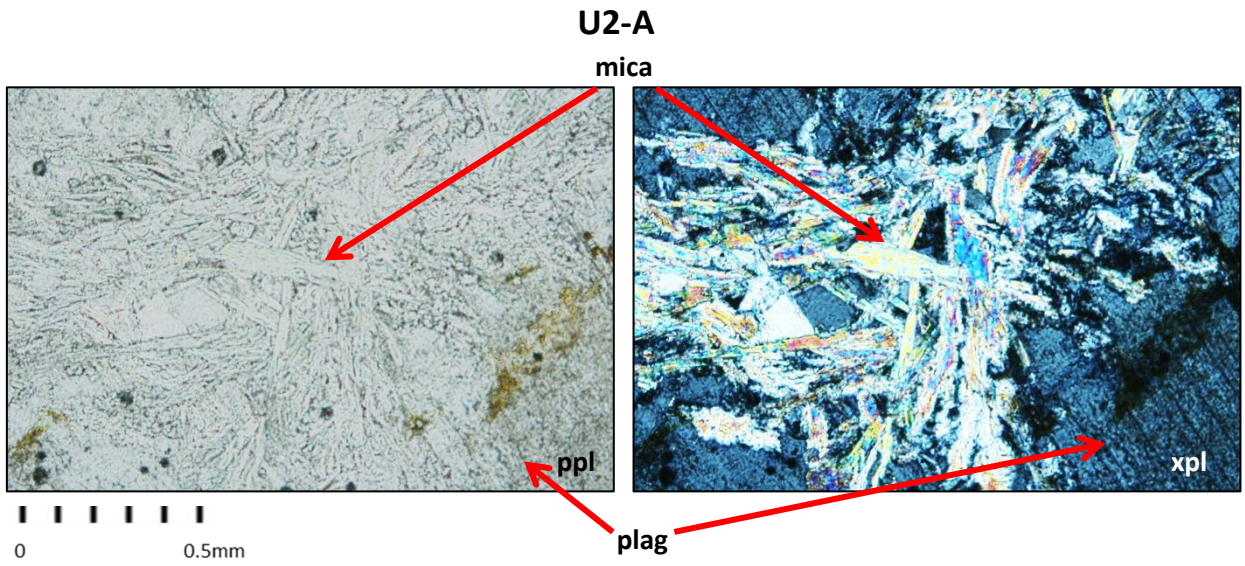


Figure 18: Thin section photomicrograph of sample U2-A

Sample U2-A was collected near a pocket. In this sample the feldspar displays incipient sericitization. This is interpreted to be the result of late-stage fluid alteration of the feldspar.

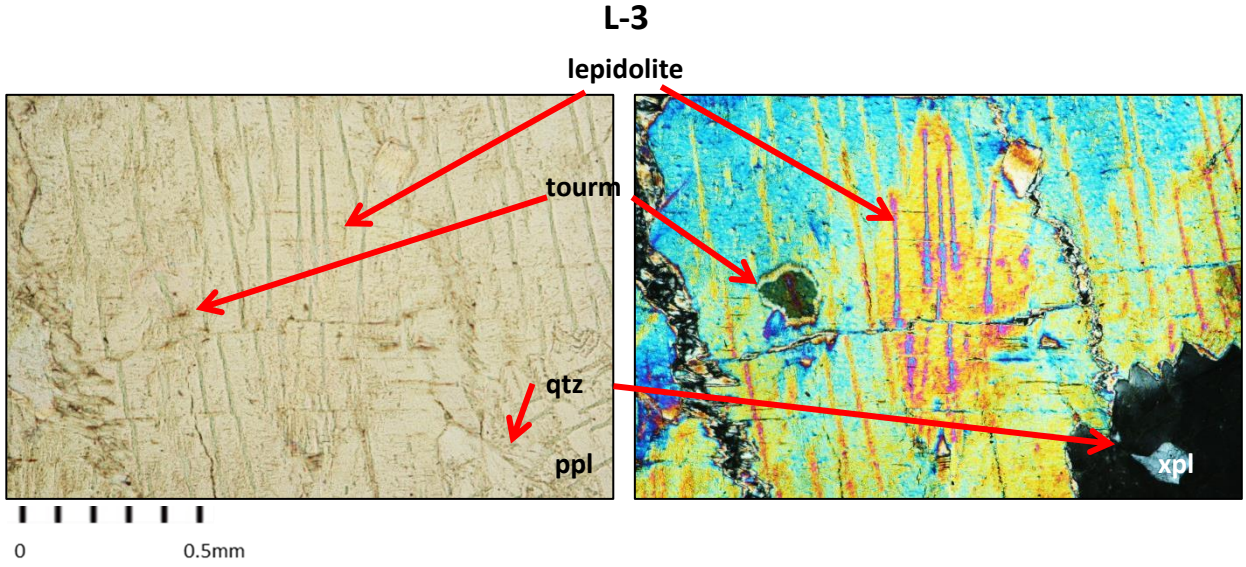


Figure 19: Thin section photomicrograph of sample L-3

Sample L-3 was collected from a lepidolite mass which was comprised of large grains of lepidolite along with accessory plagioclase, tourmaline, and quartz.

L-3

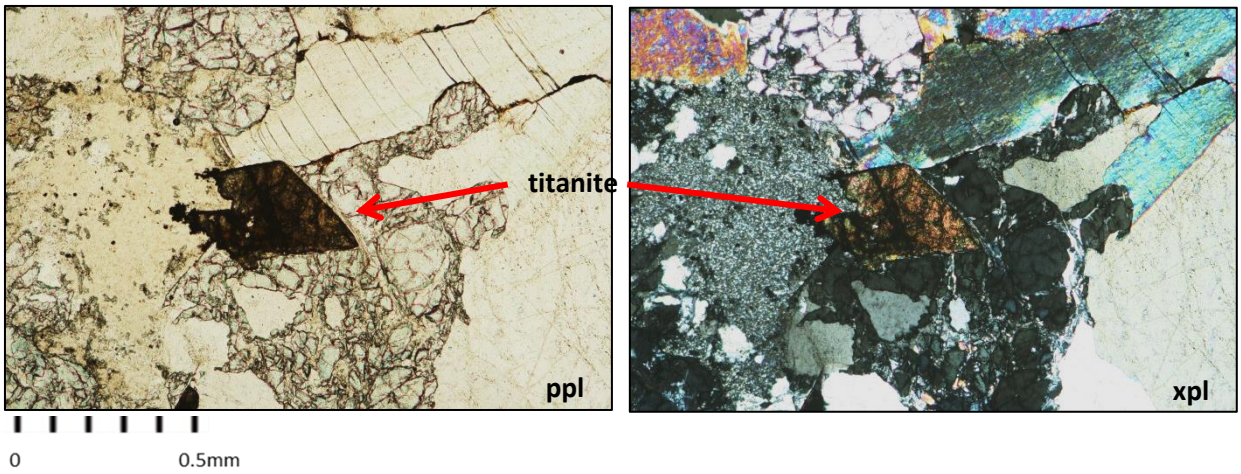


Figure 20: Thin section photomicrograph of sample L-3

A euhedral titanite crystal found within the lepidolite mass.

Mineralogy

Mica Chemistry

Figure 22: Biotite – $(Mg,Fe)_3AlSi_3O10(OH)_2$ Crystal Dimensions: 1.7 cm x 3 cm x 0.6 cm (mindat.org)

Figure 21: Muscovite with Lepidolite rim. Size: 6.5 cm x 4.5 cm (mindat.org)

Mica is the third most abundant constituent of most pegmatite types (Hawthorne & Černý 1982) and is a ubiquitous component of all samples from the Usakos pegmatite. Samples containing mica were gathered from the pegmatite-country rock contact, intermediate areas, lepidolite masses, and in and around pockets. A total of 31 mica samples were manually separated, identified and imaged via SEM and quantitatively analyzed via electron microprobe. Li was calculated based on Tischendorf's (1997) calculation for estimating Li= 0.3935*F^1.326 and verified by DCP analyses. H_2O was iteratively calculated based on stoichiometry. For this study 88 microprobe analyses were used and a representative sample is presented in table 2.

Mica minerals are phyllosilicates and structurally are composed of a sheet of octahedrally coordinated cations bounded on either side by a layer of $(Si, Al)O_4$ tetrahedra

(Simmons *et al.* 2003). Al in the octahedral site, is replaced by Li as the composition of the mica becomes more evolved. For biotite compositions, the Al values are lower due to the abundance of Fe and Mg in the octahedral site. Micas range in composition from lithium-muscovite, to lepidolite, and biotite. For classification purposes, the mica has been plotted on the mica classification diagrams of Foster (1960) and Tischendorf (1997) (Figs. 23 & 24). The Li-muscovite occurs in samples from the pegmatite-country rock contact to areas in and around pockets and is the most prominent composition present at the Usakos pegmatite. Biotite was only found in one sample at the pegmatite-country rock contact. The biotite formed large blades 8 cm in diameter inter-grown with feldspar and garnet. Lepidolite was gathered from lepidolite masses and is commonly associated with accessory elbaite, plagioclase, and highly evolved species from the pyrochlore super-group, columbite-tantalite series, and zircon.

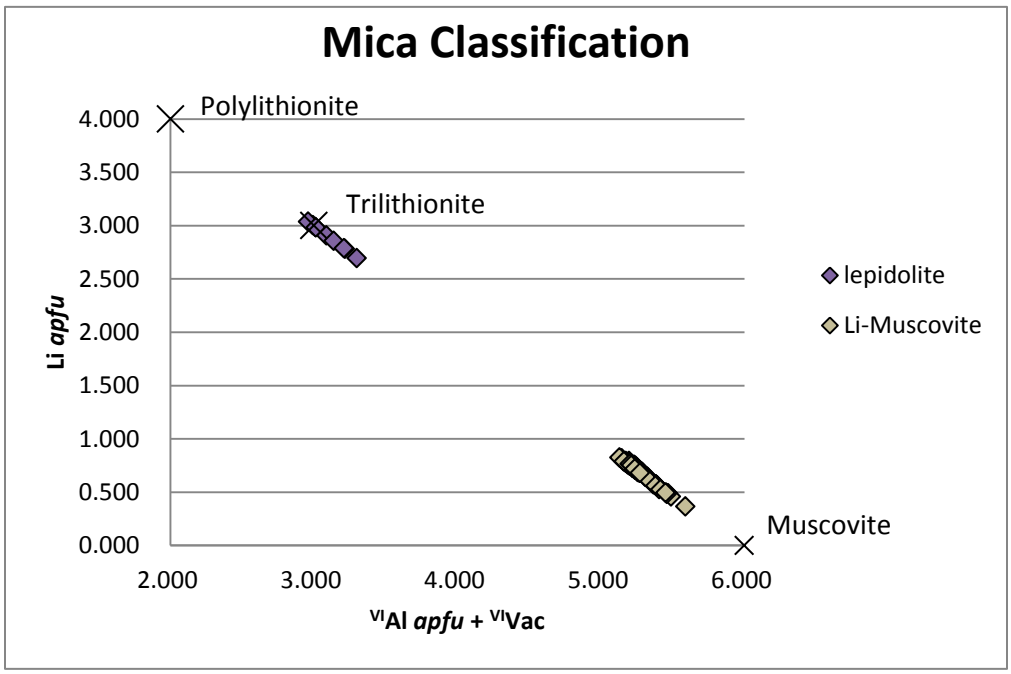


Figure 23: Mica Classification based on Li *apfu vs* ^{VI}Al *apfu* + ^{VI}Vac *apfu* (Foster 1960)

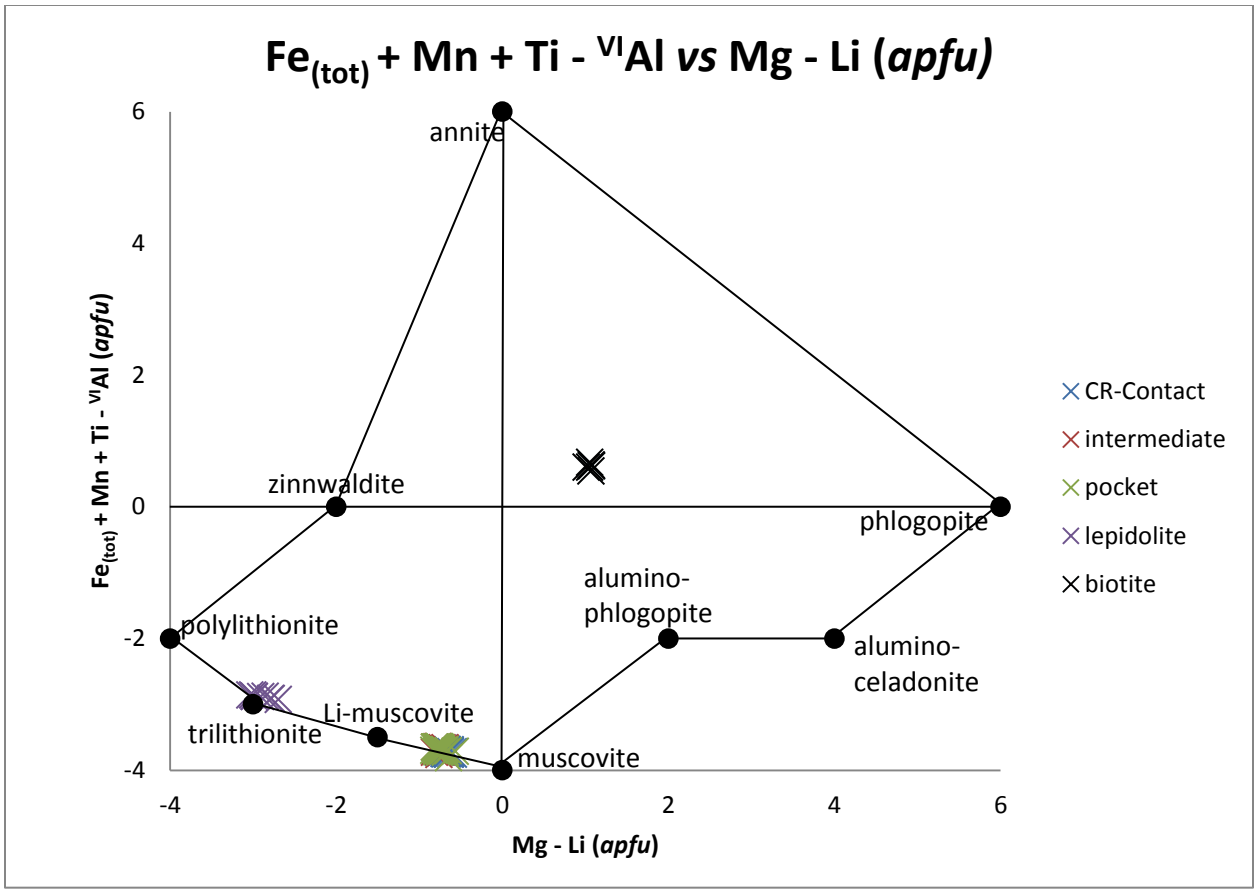


Figure 24: Fe $_{(tot)}$ + Mn + Ti - ^{VI}Al *vs* Mg - Li (*apfu*). Classification Diagram (Tischendorf (1997) with end member compositions plotted as black dots.

The K/Rb ratio and Cs content of micas can be used to describe the degree of pegmatite evolution and the internal process of fractional crystallization within the pegmatite (Alfonso *et al*. 2003; Černý 2005; Roda *et al*. 2007). The Tanco pegmatite is a well-known highly-evolved pegmatite with published K/Rb ratios for Li-muscovite and lepidolite of 3.0-1.6 and 3.8-1.6 respectively (Černý 2005).

In the Usakos pegmatite, the K/Rb ratio decreases and the Cs content increases from the pegmatite country rock contact to the most evolved areas in the interior of the pegmatite. At the country rock pegmatite contact the K/Rb ratio has an average of 97, in the more intermediate areas of the pegmatite the K/Rb ratio average is 17 and in the core areas where

lepidolite is present the K/Rb average ratio is 6. Fig. 25 clearly shows the fractionation trend of increasing Rb and Cs during crystallization.

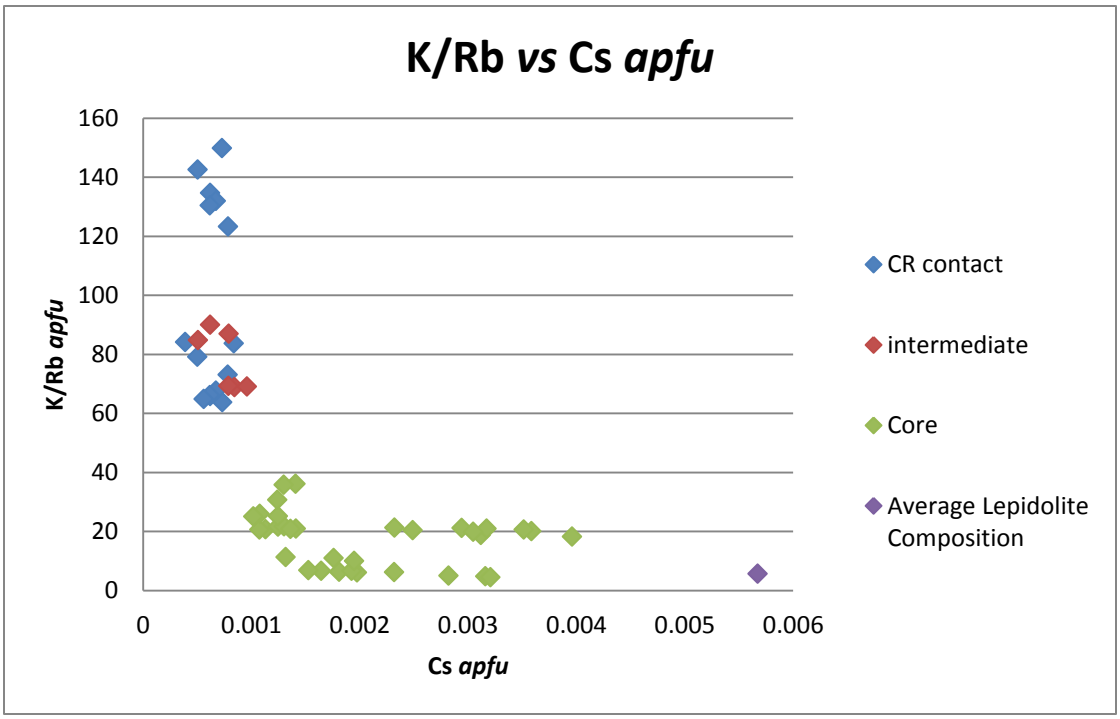


Figure 25: K/Rb *vs* Cs *apfu* plot displaying internal evolution of Usakos pegmatite.

The Si+Li *vs* total Al *apfu* (Fig. 26) diagram displays the evolutionary trends in micas between Li and Al. There is a small increase in Li from contact to core samples with a marked increase of Li in lepidolite samples. In the biotite samples Li is not an important constituent although some Li has been calculated to be present.

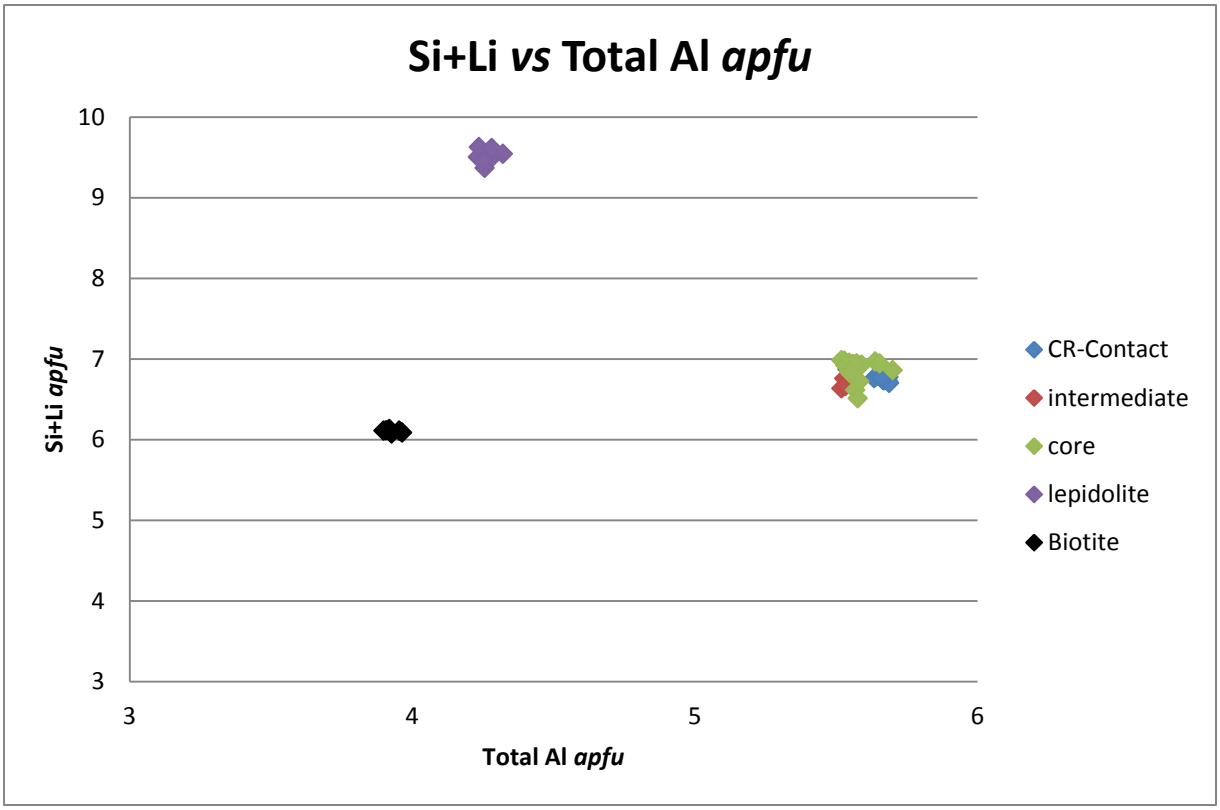


Figure 26: Si+Li *vs* Total Al *apfu* plot. Usakos Mica species

Table 2. Representative Microprobe Analyses of Mica from the Usakos Pegmatite.

Usakos micas oxide	L2-2	L2-3	G7-2	1.7-2	U9B-3	U10B-1	CZ3A-3	CZ6-3	CZ2-1
SiO_2	50.895	50.994	46.734	45.875	46.412	46.66	46.311	46.399	38.550
TiO_2	0.000	0.000	0.018	0.013	0.011	0.02	0.011	0.013	0.760
Al_2O_3	27.595	27.622	35.595	36.371	35.6	35.77	36.654	36.566	23.343
FeO	0.009	0.012	0.255	0.412	0.393	0.303	0.298	0.365	16.340
MnO	0.013	0.011	0.142	0.061	0.048	0.033	0.045	0.063	0.101
MgO	0.000	0.000	0.000	0.000	0	0	0.000	0.000	7.454
CaO	0.019	0.017	0.074	0.114	0.064	0.045	0.092	0.080	0.082
Na_2O	0.312	0.334	0.300	0.512	0.393	0.333	0.273	0.316	0.330
K_2O	8.500	8.312	7.993	10.111	9.36	9.78	10.032	9.845	8.930
Rb_2O	2.277	2.430	2.720	0.194	0.765	0.44	0.109	0.247	0.023
Cs_2O	0.088	0.103	0.056	0.009	0.054	0.025	0.013	0.010	0.000
Li_2O calc	5.289	5.308	1.374	1.335	1.483	1.288	1.211	1.288	0.916
H_2O	1.221	1.219	3.318	3.356	3.243	3.382	3.453	3.407	3.265
F	7.096	7.115	2.567	2.512	2.72	2.445	2.334	2.445	1.891
subtotal	103.31	103.48	101.14	100.88	100.546	100.524	100.836	101.044	101.985
F=O	2.988	2.996	1.081	1.058	1.145	1.029	0.983	1.029	0.796
Total	**100.36**	**100.48**	**100.06**	**99.817**	**99.401**	**99.494**	**99.853**	**100.01**	**101.19**
apfu									
Si	6.658	6.660	6.181	6.051	6.142	6.163	6.093	6.095	5.556
Ti	0.000	0.000	0.002	0.001	0.001	0.002	0.001	0.001	0.082
Al	4.254	4.251	5.548	5.654	5.552	5.568	5.683	5.661	3.965
Fe	0.001	0.001	0.028	0.045	0.043	0.033	0.033	0.040	1.969
Mn	0.001	0.001	0.016	0.007	0.005	0.004	0.005	0.007	0.012
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.601
Ca	0.003	0.002	0.010	0.016	0.009	0.006	0.013	0.011	0.013
Na	0.079	0.085	0.077	0.131	0.101	0.085	0.070	0.080	0.092
K	1.418	1.385	1.348	1.701	1.580	1.648	1.684	1.650	1.642
Rb	0.233	0.249	0.282	0.020	0.079	0.046	0.011	0.025	0.003
Cs	0.005	0.006	0.003	0.001	0.003	0.001	0.001	0.001	0.000
Li	2.782	2.788	0.731	0.708	0.789	0.684	0.641	0.680	0.531
OH	1.065	1.062	2.926	2.952	2.862	2.979	3.029	2.984	3.138
F	2.935	2.938	1.074	1.048	1.138	1.021	0.971	1.016	0.862
Al T	1.342	1.340	1.819	1.949	1.858	1.837	1.907	1.905	2.444
Al Oct	2.912	2.911	3.728	3.705	3.695	3.731	3.775	3.756	1.521
Tet site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct Site	5.696	5.702	4.505	4.467	4.534	4.454	4.455	4.484	5.717
Alkali site	1.738	1.726	1.721	1.869	1.772	1.786	1.778	1.767	1.749
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Table 2: Representative compositions of various mica species based on 24 anions. Lilac: lepidolite; Beige: Li-muscovite; Gray: Biotite.

In addition to being an important rock forming mineral in the body of the pegmatite, micas of different species may also be present as well formed crystals found in miarolitic cavities within the pegmatite. These crystal often exhibit interesting chemical zoning. One such crystal was encased in epoxy and examined via the scanning electron microscope both perpendicular and parallel to the cleavage plane. The composition was very interesting; at the core of the crystal there was more Si than Al with an increase in Mn which is indicative of lepidolite, the crystal was rimmed with a composition closer to Li-muscovite with Al greater than Si and Mn. The streaks in the outer portion are lepidolitic in composition. Figures 27-28 show SEM element maps of parallel and perpendicular to cleavage views of the sample. Al is depicted as the green color, Si is red, and Mn is purple.

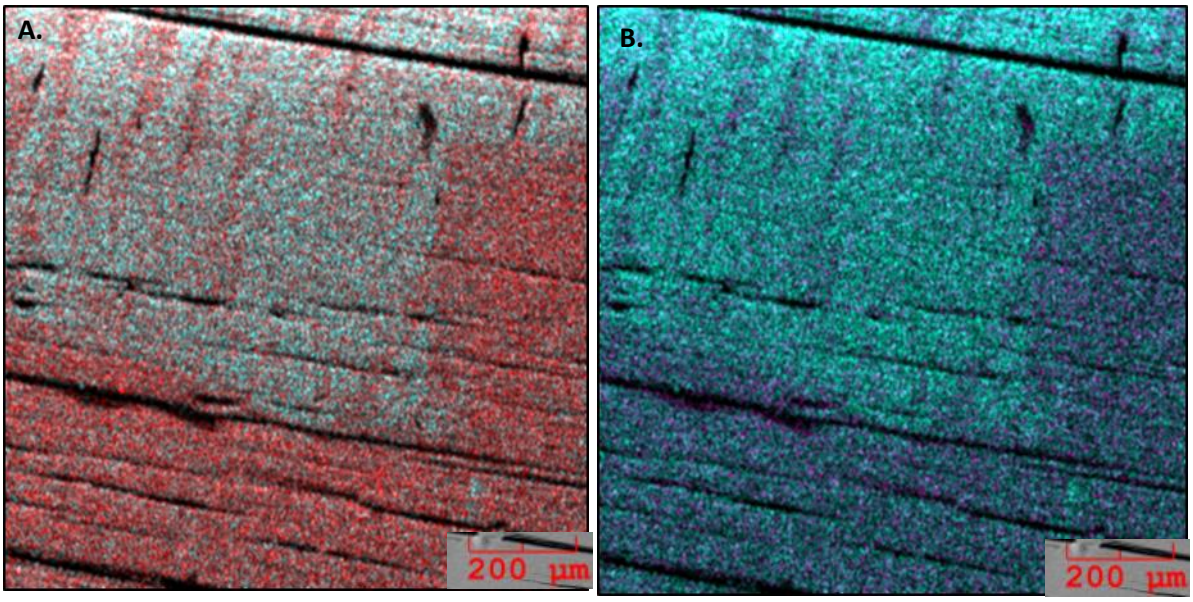


Figure 27: Scanning electron image of zoned mica crystal perpendicular to cleavge. A. Al vs Si: Si – Red, Al – Green B. Al vs Mn Al – Green Mn – Purple.

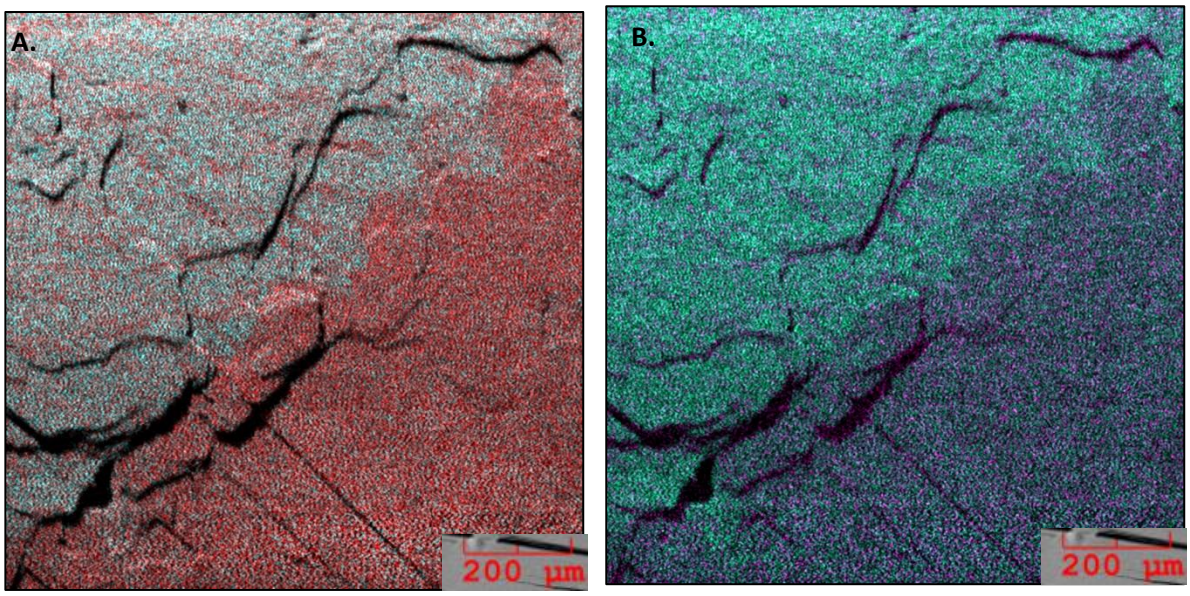


Figure 28: Scanning electron image of zoned mica crystal parallel to cleavage. A. Al vs Si: Si – Red, Al – Green B. Al vs Mn Al – Green Mn – Purple

Tourmaline

Figure 30: Tourmaline Schorl
$Na(Fe^{2+}_3)Al_6(Si_6O_{18})(BO_3)_3(OH)_3(OH)$
Dimensions: 7 cm x 5.6 cm x 5.5 cm Location: Ameib Farm 60, Usakos, Karibib District, Erongo Region, Namibia (mindat.org)

Figure 29: Tourmaline Elbaite
$Na(Li_{1.5}Al_{1.5})Al_6(Si_6O_{18})(BO_3)_3(OH)_3(OH)$
Dimensions: 2.9 cm x 2.6 cm x 0.7 cm Location: Usakos, Karibib District, Erongo Region, Namibia (mindat.org)

Tourmaline contributes to the overall economic importance of pegmatites as it is a very desirable gem that commands a high dollar value. The Usakos pegmatite is run primarily as a mining operation for gem quality tourmaline. Tourmaline samples were gathered from the pegmatite country rock contact, intermediate areas, and in and around pockets. In addition, a suite of polychrome gem tourmaline samples were obtained from the mine owner. A total of 81 tourmaline specimens were selected and imaged using a scanning electron microscope and subsequently quantitatively analyzed via electron microprobe. Li, B, and H_2O were estimated through a series of iterative calculations based on stoichiometry. A representative Table of microprobe data for tourmaline from the Usakos pegmatite is presented in Tables 3 and 4. A

total of 187 tourmaline analyses have been used in this study. The results of the tourmaline analyses are plotted according to their natural color for ease in determining relationships of color *vs.* chemistry.

Primary tourmaline groups are classified based on the X-site occupancy yielding three primary groups: alkali, calcic, or X-site vacant groups (Henry *et al.* 2011). The Usakos pegmatite tourmaline all belong to the alkali group as Na is dominant in the X-site (Fig. 31). Tourmaline can be further classified within the alkali primary group based on the dominant cation in the Y-site. Using Fe, Mg, and Li the alkali primary group is subdivided into the dravite-schorl-elbaite subsystem (Henry *et al.* 2011). The Usakos pegmatite tourmaline ranges in composition from schorl to elbaite with very little Mg present in any sample (Fig. 32).

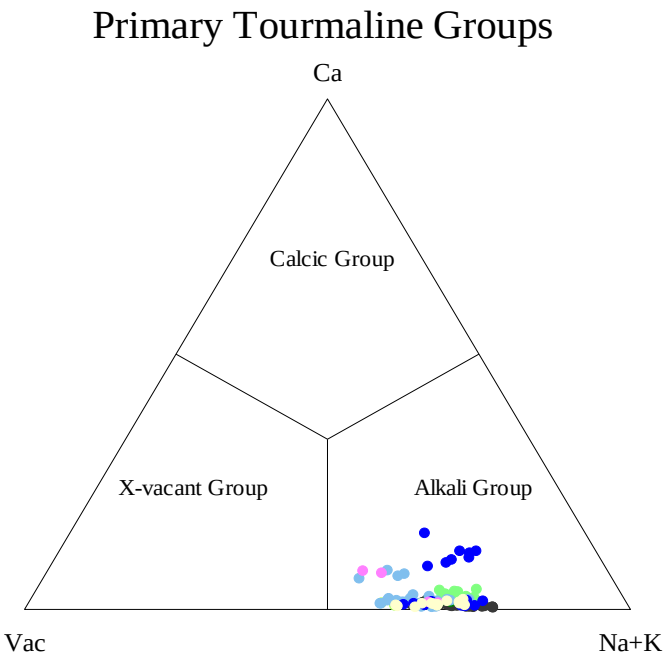


Figure 31: Primary tourmaline group based on X-site dominance. (Henry *et al.* 2011)

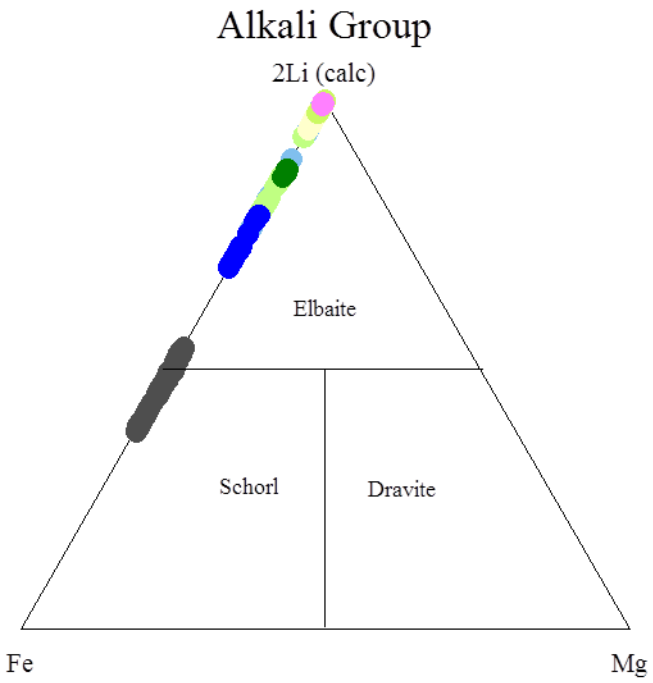


Figure 32: Alkali subgroup based on the Dravite-Schorl-Elbaite ternary (Henry *et al.* 2011)

Another compositional classification is based on the dominance of the W-site. At the W-site OH, F, and O can be present. If F is dominant, the prefix fluor- is attached to the species name. The Usakos pegmatite tourmalines are F-dominant in the W-site (Fig. 33) so they are termed fluor-schorl and fluor-elbaite.

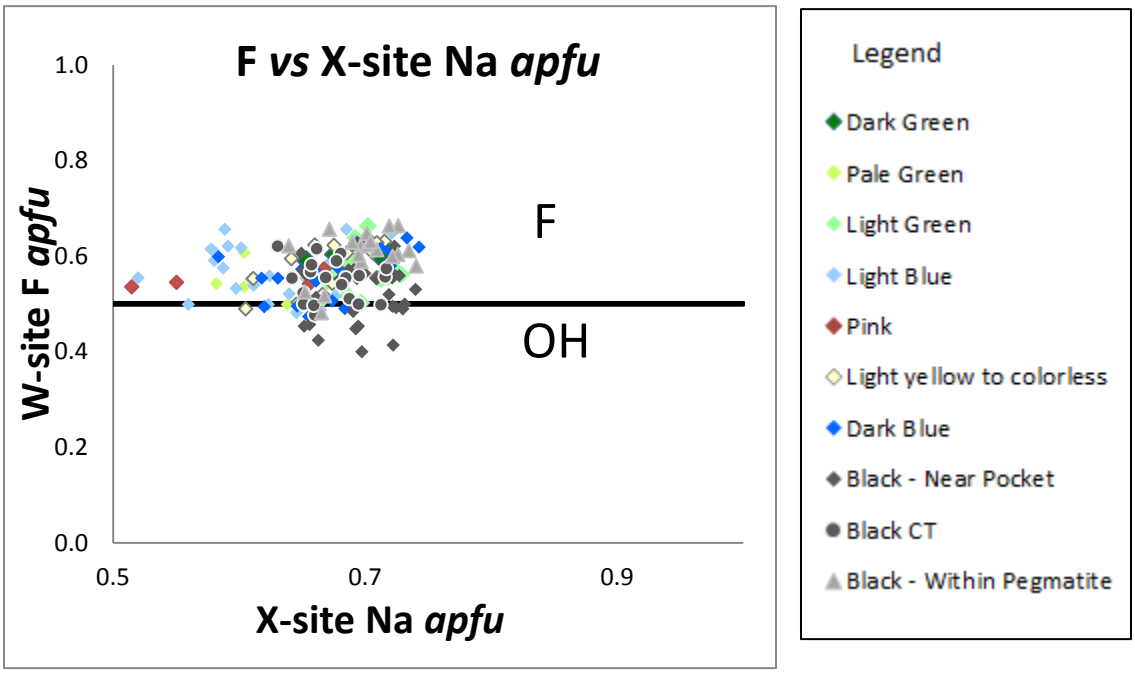


Figure 33: F *vs* X-site Na *apfu*. Display of the F dominance of the tourmaline from the Usakos pegmatite.

Table 3. Representative Microprobe Analyses of Colored Tourmaline from the Usakos Pegmatite

Sample	CT.8-1	CT.13-4	CT.3-3	CT.4-1	CT.10-2	G8.3-2	G8.10-1
SiO_2	37.763	37.672	37.600	37.623	37.557	36.634	37.777
TiO_2	0.000	0.000	0.000	0.000	0.022	0.000	0.033
B_2O_3 calc.	11.106	11.200	11.088	11.073	10.875	10.819	10.956
Al_2O_3	42.009	42.277	41.720	41.571	38.730	39.466	39.551
FeO	0.167	0.191	0.734	0.674	4.784	3.437	2.566
MnO	0.412	0.344	0.540	0.650	0.432	1.177	1.092
CaO	0.073	0.454	0.082	0.064	0.032	0.139	0.084
ZnO	0.000	0.012	0.009	0.000	0.022	0.015	0.009
Li_2O calc.	2.008	2.168	1.947	1.946	1.557	1.574	1.741
Na_2O	2.200	1.712	2.334	2.320	2.183	2.341	2.255
K_2O	0.044	0.032	0.009	0.034	0.000	0.022	0.018
H_2O calc.	3.283	3.348	3.295	3.241	3.267	3.156	3.200
F	1.158	1.091	1.119	1.223	1.022	1.216	1.223
Subtotal	**100.222**	**100.501**	**100.476**	**100.419**	**100.483**	**99.996**	**100.551**
O=F	0.488	0.459	0.471	0.515	0.430	0.512	0.515
Total	**99.734**	**100.041**	**100.005**	**99.904**	**100.053**	**99.484**	**100.036**
apfu							
Si	5.909	5.844	5.893	5.905	6.003	5.885	5.992
Ti	0.000	0.000	0.000	0.000	0.003	0.000	0.004
B	3.000	2.999	3.000	3.000	3.000	3.000	3.000
Al	7.749	7.731	7.708	7.690	7.296	7.472	7.394
Fe^{2+}	0.022	0.025	0.096	0.088	0.639	0.462	0.340
Mn	0.055	0.045	0.072	0.086	0.058	0.160	0.147
Ca	0.012	0.075	0.014	0.011	0.005	0.024	0.014
Zn	0.000	0.001	0.001	0.000	0.003	0.002	0.001
Li	1.264	1.353	1.227	1.228	1.001	1.017	1.111
Na	0.668	0.515	0.709	0.706	0.677	0.729	0.694
K	0.009	0.006	0.002	0.007	0.000	0.005	0.004
H	3.427	3.465	3.445	3.393	3.483	3.382	3.386
F	0.573	0.535	0.555	0.607	0.517	0.618	0.614

Table 3: Representative suite of microprobe analyses of Usakos colored tourmaline. Analyses based on 31 anions. Color corresponds to the natural color of the tourmaline.

Table 4. Representative Microprobe Analyses of Schorl from the Usakos Pegmatite.

Sample	U9-2	U15-3	U17-2	CZ2-3	G1-1	G2-2
SiO_2	36.788	36.672	36.644	36.700	36.512	36.612
TiO_2	0.260	0.238	0.213	0.213	0.196	0.236
B_2O_3 calc.	10.383	10.352	10.353	10.361	10.326	10.336
Al_2O_3	32.165	32.145	32.005	32.092	31.912	31.901
FeO	12.445	12.510	12.777	12.672	12.799	12.882
MnO	0.756	0.744	0.712	0.709	0.707	0.600
CaO	0.059	0.054	0.037	0.034	0.031	0.039
ZnO	0.011	0.018	0.011	0.009	0.015	0.014
Li_2O calc.	1.127	1.087	1.089	1.094	1.082	1.100
Na_2O	2.122	2.022	2.223	2.133	2.310	2.200
K_2O	0.024	0.028	0.026	0.041	0.015	0.017
H_2O calc.	3.208	3.159	3.035	3.097	3.099	3.048
F	0.790	0.872	1.134	1.009	0.978	1.093
Subtotal	**100.194**	**99.949**	**100.302**	**100.214**	**100.020**	**100.106**
O=F	0.333	0.367	0.477	0.425	0.412	0.460
Total	**99.862**	**99.581**	**99.825**	**99.789**	**99.608**	**99.646**
apfu						
Si	6.157	6.157	6.151	6.156	6.145	6.156
Ti	0.033	0.030	0.027	0.027	0.025	0.030
B	3.000	3.000	3.000	3.000	3.000	3.000
Al	6.346	6.361	6.332	6.345	6.331	6.322
Fe^{2+}	1.742	1.756	1.794	1.778	1.802	1.811
Mn	0.107	0.106	0.101	0.101	0.101	0.085
Ca	0.011	0.010	0.007	0.006	0.006	0.007
Zn	0.001	0.002	0.001	0.001	0.002	0.002
Li	0.759	0.734	0.735	0.738	0.732	0.744
Na	0.689	0.658	0.724	0.694	0.754	0.717
K	0.005	0.006	0.006	0.009	0.003	0.004
H	3.582	3.537	3.398	3.465	3.480	3.419
F	0.418	0.463	0.602	0.535	0.521	0.581

Table 4: Representative suite of microprobe analyses of schorl tourmaline from the Usakos pegmatite. Analyses based on 31 anions.

Figure 34 shows a chemical fractionation trend from Fe-rich schorl to Fe-depleted elbaite. Interestingly, early tourmalines from close to the contact have an Fe-rich elbaitic composition. This is interpreted to be an early stage of tourmaline crystallization that interacted with the Al-rich country rock. This initial stage of tourmaline crystallization is represented in Figure 34 by the dark circles. It appears that tourmaline crystallization underwent a hiatus until the melt achieved sufficient B and H_20 concentrations to allow for schorl crystallization to commence. This secondary stage of tourmaline crystallization is represented in Figure 34 by the gray triangles. The final stage of elbaite crystallization in and around pockets displays a fractionation trend from higher Na and Fe to higher Al and X-site vacancies and is plotted according to natural color in the diamond symbol.

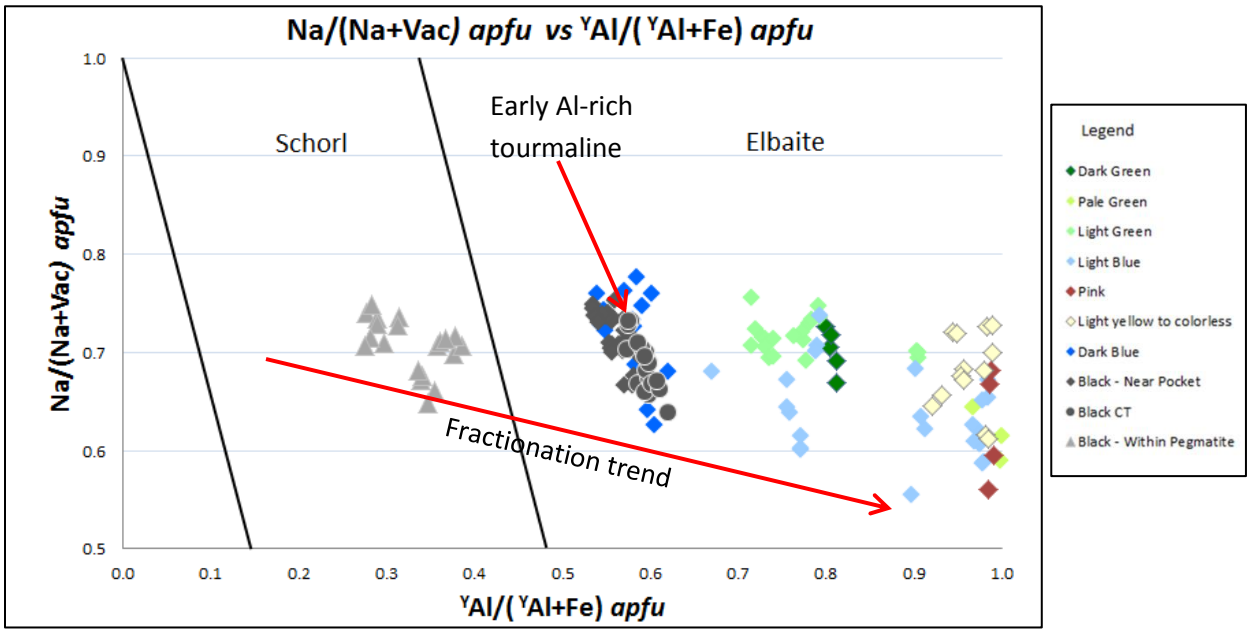
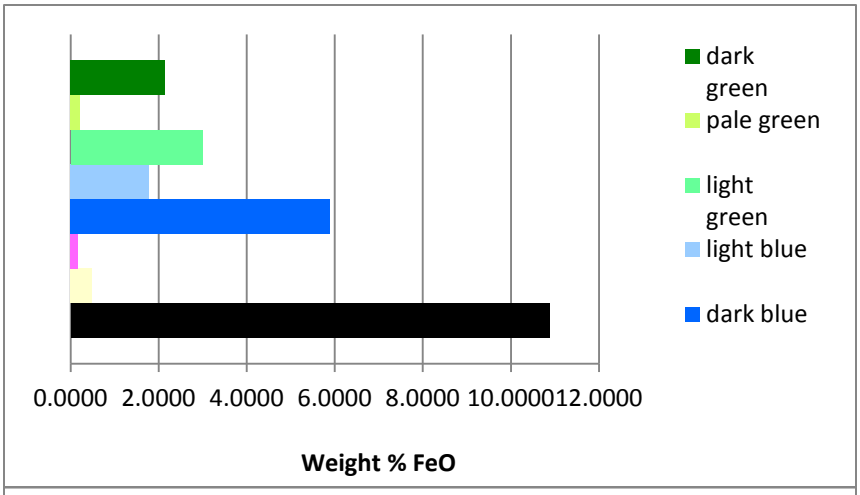


Figure 34: Na/(Na+Vac*) vs* ^{Y}Al/(^{Y}Al+Fe) *apfu* plot with tourmalines plotted according to their natural color and position within the pegmatite. (Selway *et al.* 2000)

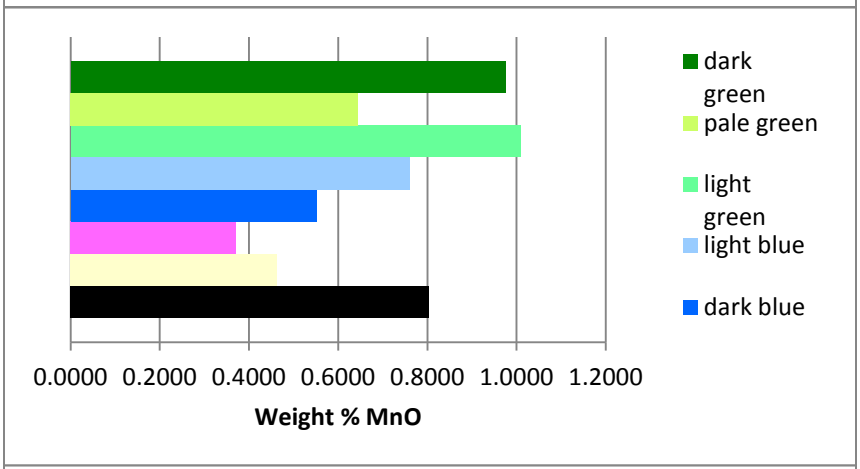
Mineral color can be correlated with chemical composition in tourmalines, and distinct color trends are apparent with the chromophoric elements Fe, Ti, and Mn (Simmons *et al.* 2005a; Simmons *et al.* 2005b). The elemental weight percent of Fe, Ti, and Mn in tourmaline are plotted in Figure 35 a-c. Fe is highest in the black tourmaline to near absent in the light and near colorless tourmalines. Fe is also present in the darker blue and green tourmalines in substantial amounts. Mn is highest in the green tourmalines with a strong showing in the black and dark blue tourmaline as well. Ti is highest in the black tourmaline and second highest in the dark green tourmaline, it is absent to virtually absent in the remaining colors.

Li is not a chromophoric element but as Fe, Ti, and Mn become depleted, Li is incorporated into the tourmaline as it crystalizes. Li is an important component of the gem quality tourmaline that is generally found in the miarolitic cavities of pegmatites.

A.



B.



C.

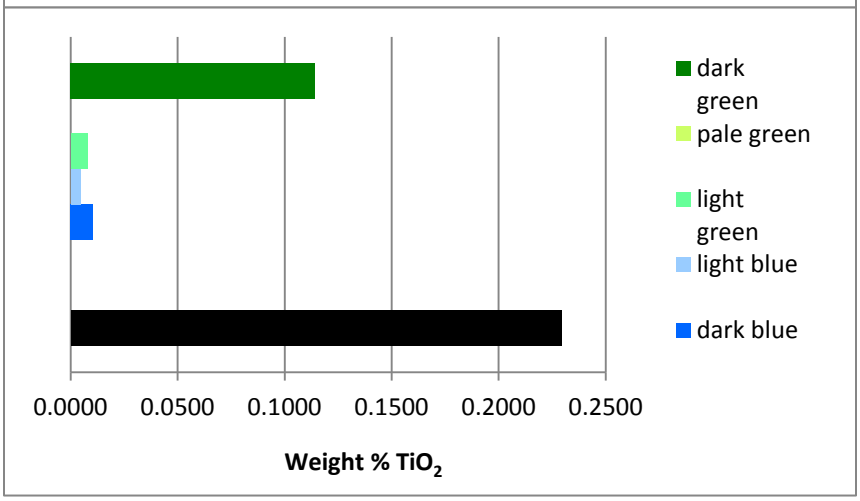


Figure 35: Correlation of Fe, Mn, and Ti oxide contents with Usakos pegmatite tourmaline color. A. FeO; B. MnO; C. TiO_2. (Simmons *et al.* 2005 B)

Feldspar Chemistry

Figure 36: Albite $NaAlSi_3O_8$ Dimensions: 13 cm x 11 cm x 5 cm (mindat.org)

Figure 37: Microcline $KAlSi_3O_8$ Dimensions: 4.06 cm x 4.56 cm x 3.81 cm (mindat.org)

Feldspar grains were manually separated from crushed rock under a microscope at 10x magnification. Grains of feldspar were obtained from all 4-regions within the pegmatite: (1) the pegmatite country rock contact, (2) < 0.5m from contact, (3) > 0.5 m from the contact and (4) in and around the pockets. The grains were mounted in epoxy, ground flat and polished in preparation for analysis. Samples were analyzed via the scanning electron microscope; this was

used to gather backscattered images and EDS spectra. The samples were then analyzed quantitatively via electron microprobe to obtain concentrations for major and minor elements in feldspar. Representative microprobe analyses for plagioclase and K-feldspar are presented in Tables 5 and 6, respectively.

Both plagioclase and K-feldspar are present in all sample areas of the Usakos pegmatite (Fig. 38). K-feldspar is more common at the pegmatite- country rock contact in the form of perthite than the other regions of the pegmatite (Fig. 39). K-feldspar was not found at the Usakos pegmatite without plagioclase. Plagioclase was found throughout the different zones of the pegmatite. In most cases the plagioclase had inclusions of K-feldspar although the number of inclusions decreased closer to pockets.

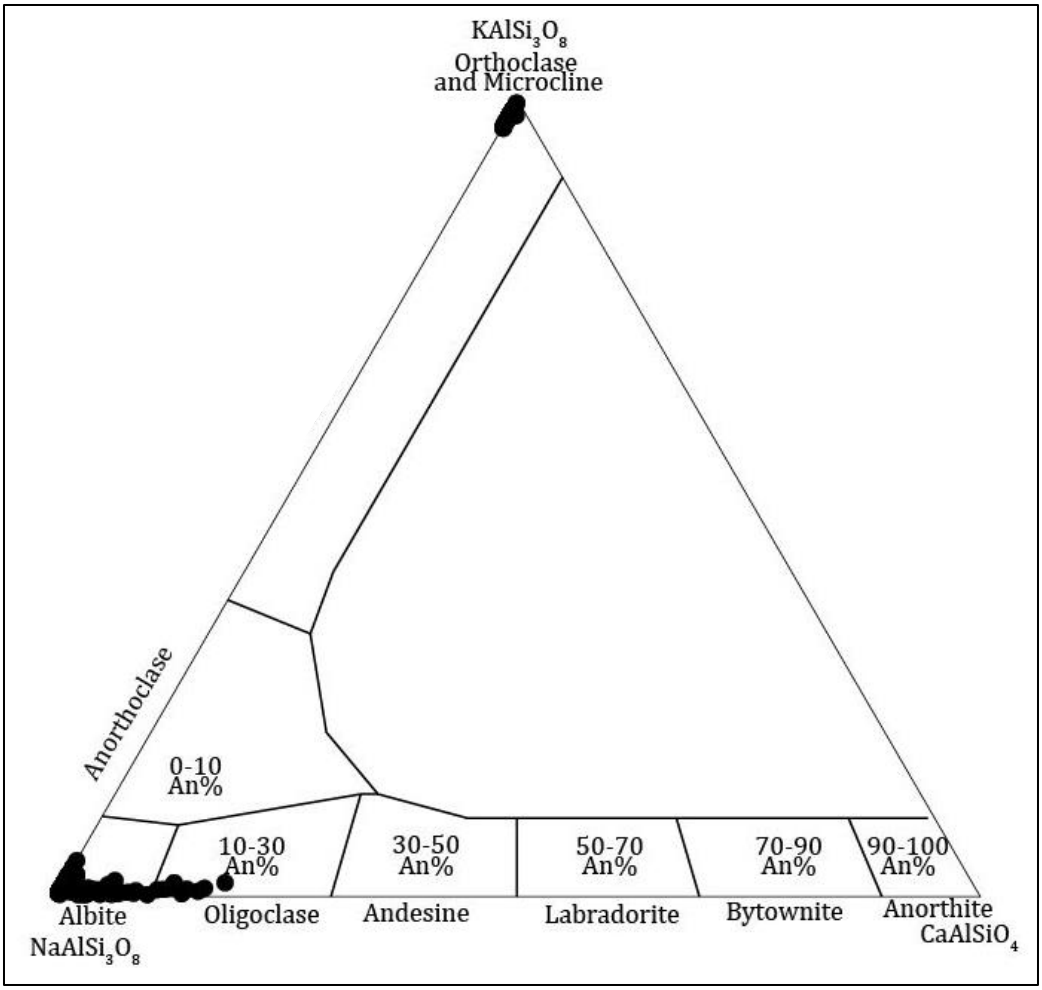


Figure 38: Ternary diagram illustrating complete range of solid solution in alkali and plagioclase feldspars with all feldspars from the Usakos pegmatite plotted.

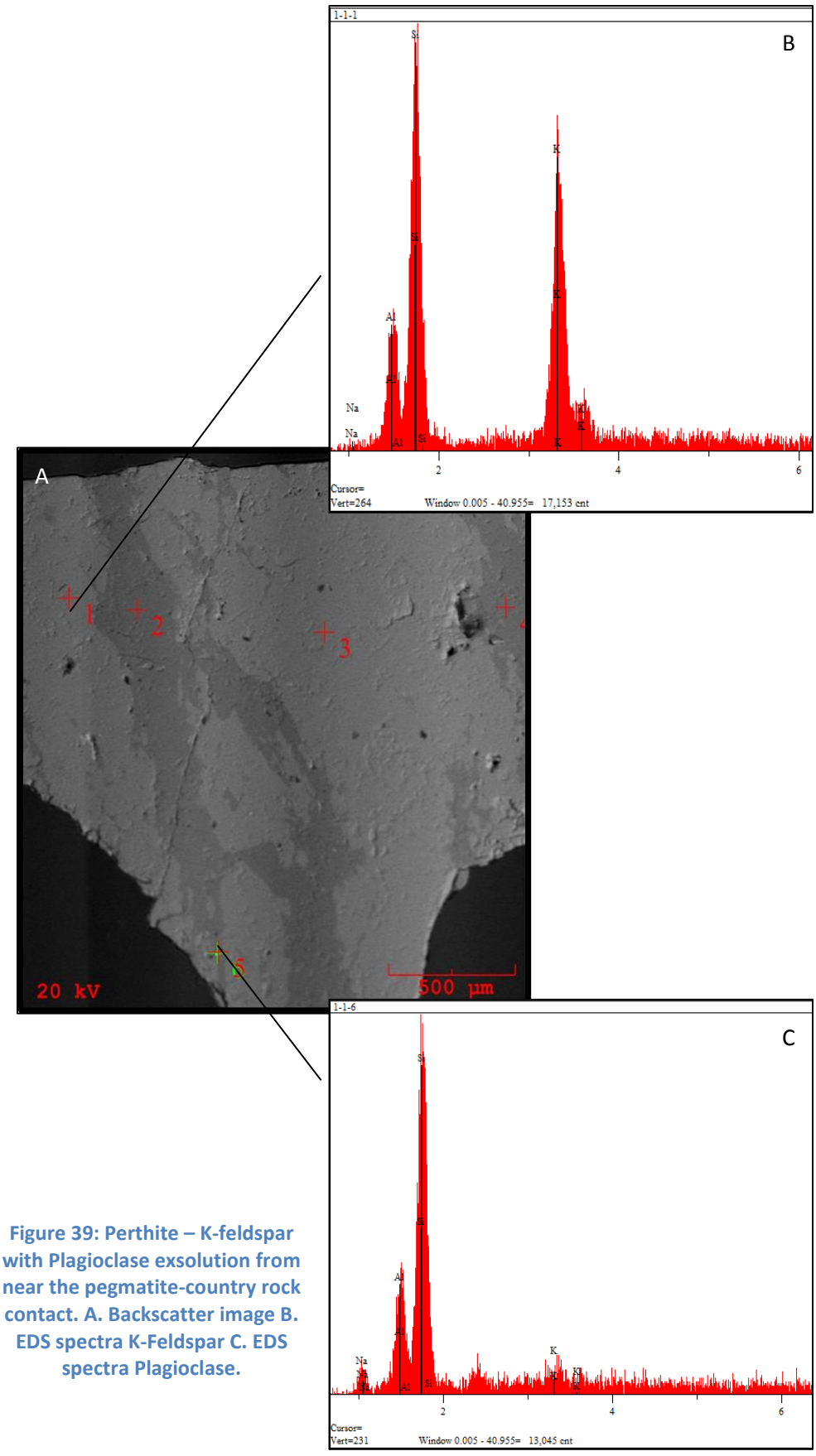


Figure 39: Perthite – K-feldspar with Plagioclase exsolution from near the pegmatite-country rock contact. A. Backscatter image B. EDS spectra K-Feldspar C. EDS spectra Plagioclase.

K-feldspar

The K/Rb ratio in K-feldspar is a well-established indicator for the evolution of a pegmatite body (Černý 1985, Alfonso, 2003). As a pegmatite body crystalizes, K is preferentially incorporated into feldspar and mica. At later more evolved stages, Rb is more available to be incorporated into feldspar. The Usakos pegmatite exhibits this trend with an average K/Rb ratio of 260 at the contact, 240 within the pegmatite but close to the contact, 139 farther within the body of the pegmatite, and 128 in and around the pockets (Fig. 40).

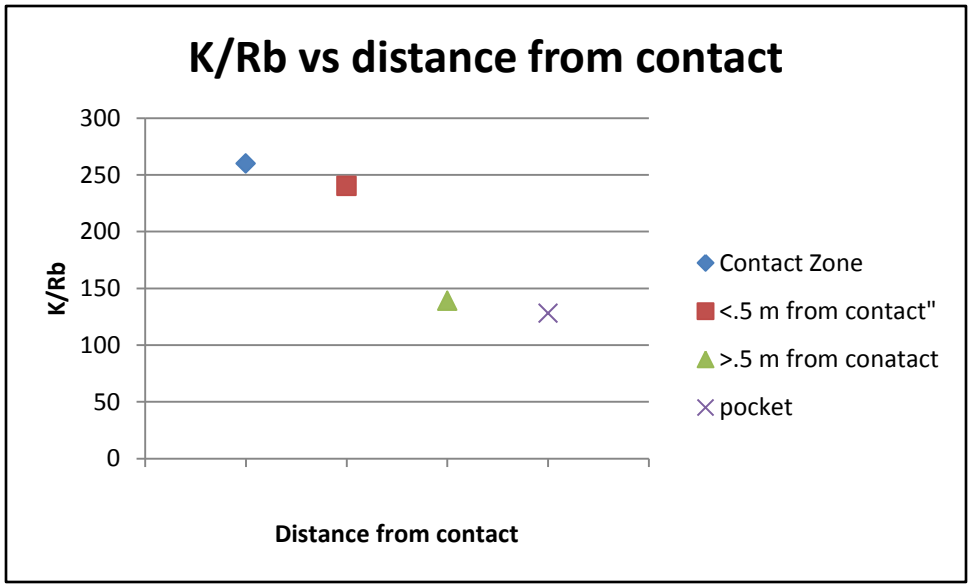


Figure 40: plot of K/Rb ratio from different areas within the pegmatite.

Another commonly used relationship to depict the internal evolution of a pegmatite body is the K/Rb vs Cs diagram (Černý 1985) (Fig. 41). In general, at the Usakos pegmatite Cs increases from contact to pocket although Cs overall is not very abundant. Notably, one sample contained feldspar with very high amounts of Cs ranging from 7.21 wt. % to 4.56 wt. % with an average of 5.07 wt. %; the average Cs *apfu* is 0.106 (Table 7). The high Cs feldspar was found within a sample of montebrasite-amblygonite.

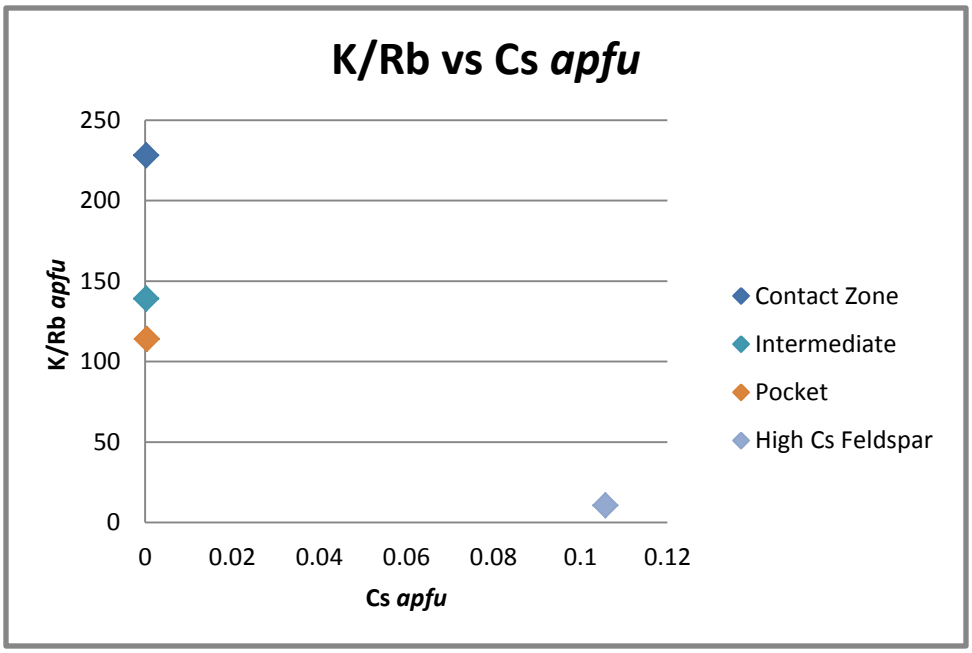


Figure 41 Plot K/Rb vs Cs for Feldspar from different regions of the Usakos Pegmatite.

Plagioclase

The anorthite component in plagioclase decreases with the degree of evolution within the body of a pegmatite (Alfonso, 2003), this phenomenon occurs at the Usakos pegmatite (Fig. 42). Anorthite content of the plagioclase is low at the contact compared to near the contact area; the low Ca content in this area may be attributed to an abundance of apatite located in that same area.

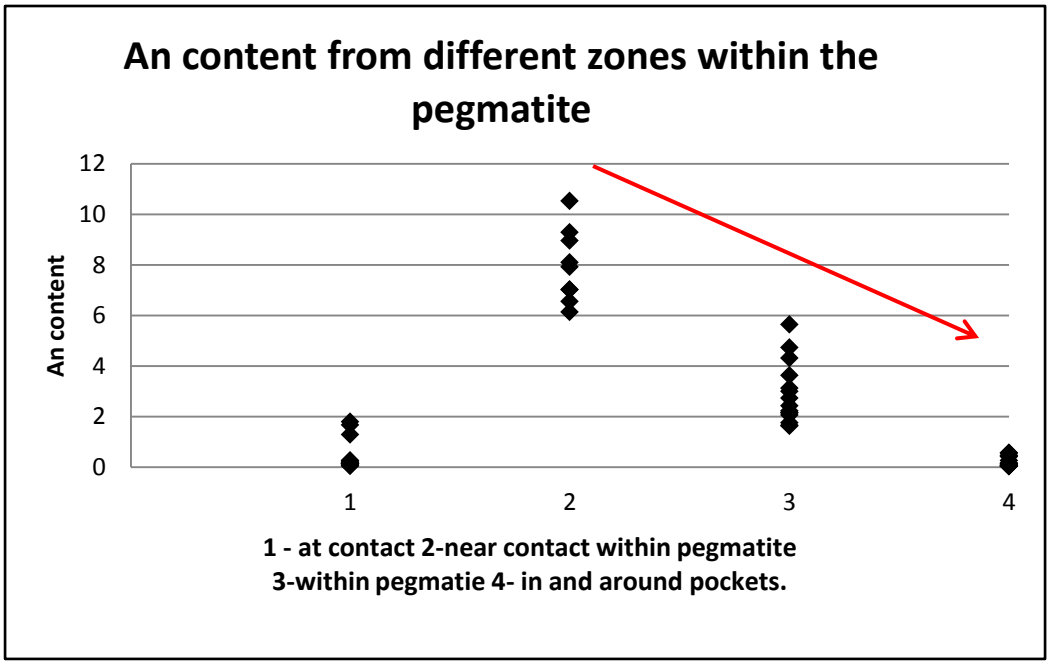


Figure 42: plot of K/Rb ratio from different areas within the pegmatite. Red arrow depicts fractionation trend.

Table 5. Representative Microprobe Analyses of Feldspar from the Usakos Pegmatite.

Feldspar	CZ-1-6	CZ3-B-4	L3-2	1.7-4	U4-4	U10A-5	U18A-4
oxide							
SiO_2	64.544	64.677	64.334	64.65	64.446	64.562	64.447
TiO_2	0.011	0.009	0.013	0.008	0	0	0
Al_2O_3	18.431	18.4	18.544	18.334	18.399	18.411	18.433
FeO	0	0.007	0	0	0	0	0
CaO	0	0	0	0	0.011	0	0
K_2O	16.522	16.44	16.32	16.446	16.344	16.56	16.44
Na_2O	0.2	0.211	0.434	0.322	0.445	0.255	0.344
P_2O_5	0.022	0.032	0.013	0.032	0	0.019	0.032
Rb_2O	0.134	0.122	0.122	0.233	0.255	0.199	0.312
Cs2O	0.016	0.013	0	0.011	0.025	0	0.022
Total	**99.88**	**99.911**	**99.78**	**100.036**	**99.925**	**100.006**	**100.03**
apfu							
Si	2.993	2.996	2.986	2.995	2.991	2.993	2.989
Ti	0.001	0.000	0.001	0.001	0	0	0
Al	1.007	1.005	1.014	1.001	1.006	1.006	1.008
Fe	0	0.000	0	0	0	0	0
Ca	0	0	0	0	0.001	0	0
K	0.977	0.971	0.966	0.972	0.968	0.979	0.973
Na	0.018	0.019	0.039	0.029	0.040	0.023	0.031
P	0.001	0.001	0.001	0.001	0	0.001	0.001
Rb	0.004	0.004	0.004	0.007	0.008	0.006	0.009
Cs	0.000	0.000	0	0.000	0.001	0	0.000
An	0	0	0	0	0.0545	0	0
Ab	1.807	1.913	3.885	2.890	3.971	2.286	3.082
Or	98.194	98.088	96.115	97.110	95.974	97.713	96.918

Table 5: Representative microprobe analyses of feldspar from the Usakos pegmatite calculated based on 8 oxygen.

Table 6. Representative Microprobe Analyses of Plagioclase from the Usakos Pegmatite.

Plagioclase	CZ-1-1	CZ5-2	CZ8-2	G1-1	1.5-2	U3-2	U10A-2	U17-1	U18A-1
oxide									
SiO_2	68.774	68.455	69.122	69.243	68.345	68.612	68.612	68.311	68.4
TiO_2	0	0	0	0	0	0	0	0	0
Al_2O_3	19.512	19.388	19.477	19.444	19.65	19.388	19.599	19.773	19.393
FeO	0	0	0	0	0	0	0	0	0
MgO	0	0	0	0	0	0	0	0	0
CaO	0.355	0.011	0.008	0.189	0.455	0	0	0.656	0.009
MnO	0	0	0	0	0	0	0	0	0
K_2O	0.023	0.188	0.067	0.1	0.064	0.214	0.088	0.055	0.355
Na_2O	11.56	11.55	11.688	11.65	11.4	11.744	11.64	11.211	11.655
P_2O_5	0	0		0	0.011	0	0	0	0
SrO	0	0	0	0	0	0	0	0.008	0
Total	**100.224**	**99.592**	**100.362**	**100.626**	**99.925**	**99.958**	**99.939**	**100.014**	**99.812**
apfu									
Si	2.996	3.001	3.004	3.004	2.987	2.999	2.996	2.983	2.996
Ti	0	0	0	0	0	0	0	0	0
Al	1.002	1.002	0.998	0.994	1.012	0.999	1.009	1.018	1.001
Fe	0	0	0	0	0	0	0	0	0
Mg	0	0	0	0	0	0	0	0	0
Ca	0.017	0.001	0.000	0.009	0.021	0	0	0.031	0.000
Mn	0	0	0	0	0	0	0	0	0
K	0.001	0.011	0.004	0.006	0.004	0.012	0.005	0.003	0.019
Na	0.976	0.981	0.985	0.980	0.966	0.995	0.985	0.949	0.990
P	0	0	0	0	0.000	0	0	0	0
Sr	0	0	0	0	0	0	0	0.000	0
An	1.666	0.052	0.038	0.884	2.150	0	0	3.123	0.0418
Ab	98.204	98.889	99.586	98.559	97.489	98.815	99.505	96.565	97.994
Or	0.128	1.059	0.375	0.556	0.360	1.184	0.494	0.311	1.963

Table 6: Representative microprobe analyses of plagioclase from the Usakos pegmatite calculated based on 8 oxygen.

Table 7. Microprobe Analyses of High-Cs Bearing Feldspars.

Feldspars	M2-1	M2-2	M2-3	M2-4	M2-5	M2-6	M2-7
oxide	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %
SiO_2	60.93	61.777	61.454	61.334	61.284	61.523	61.223
Al_2O_3	17.412	17.512	17.499	17.445	17.561	17.485	17.5
K_2O	12.823	12.782	12.434	12.267	12.723	12.531	12.782
Na_2O	0.111	0.133	0.145	0.132	0.109	0.132	0.132
Rb_2O	1.33	2.88	2.57	2.67	2.67	2.87	2.43
Cs_2O	7.21	4.57	4.76	4.89	4.56	4.77	4.77
Total	99.821	99.651	98.857	98.737	98.913	99.308	98.833
apfu							
Si	2.992	3.001	3.002	3.004	2.996	3.001	2.996
Al	1.008	1.003	1.008	1.007	1.012	1.005	1.009
K	0.803	0.792	0.775	0.766	0.793	0.780	0.798
Na	0.011	0.013	0.014	0.013	0.010	0.012	0.013
Rb	0.042	0.090	0.081	0.084	0.084	0.090	0.076
Cs	0.151	0.095	0.099	0.102	0.095	0.099	0.099
X-site	1.007	0.989	0.968	0.965	0.983	0.981	0.986
Y-site	1.008	1.003	1.008	1.007	1.012	1.005	1.009
Z-site	2.992	3.001	3.002	3.004	2.996	3.001	2.996
K/Rb	19.078	8.802	9.621	9.112	9.450	8.660	10.440

Table 7: Microprobe analyses of high Cs bearing feldspars. Calculated on the basis of 8 oxygens.

Apatite Chemistry

Figure 43: Apatite $Ca_5(PO_4)_3F$ Dimensions: 4.8 cm x 3.7 cm x 3.4 cm (mindat.org)

Apatite, a calcium phosphate [$Ca_5(PO_4)_3F$], is a common accessory mineral associated with pegmatites. At the Usakos pegmatite it occurs as a primary phase in the outer portions of the pegmatite and in the lepidolite masses. The crystals are generally subhedral, the largest crystals are approximately 3mm in length and commonly have a greenish color. In addition, apatite commonly occurs as inclusions within feldspar grains and as a secondary overgrowth on minerals throughout the pegmatite.

Microprobe analysis was conducted on apatite from the outer portions of the pegmatite and inclusions from within feldspar. The results are presented in Table 8. The green columns are the primary phases of apatite and the gray columns are apatite analyses from inclusions within feldspars. The apatite is F-dominant in the Z-site (Fig. 44) so the term fluorapatite is appropriate for the Usakos pegmatite apatite. In addition, Mn is the most abundant replacement element for Ca in the X-site (Fig. 45).

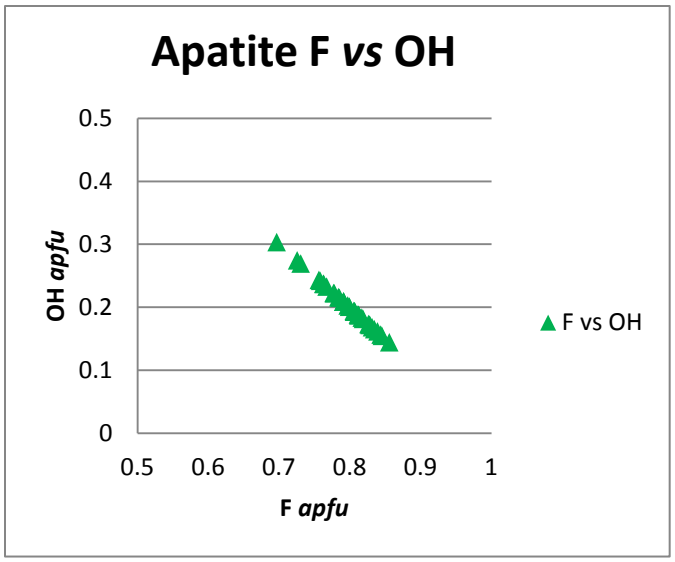


Figure 44: F *vs* OH plot determining fluorapatite.

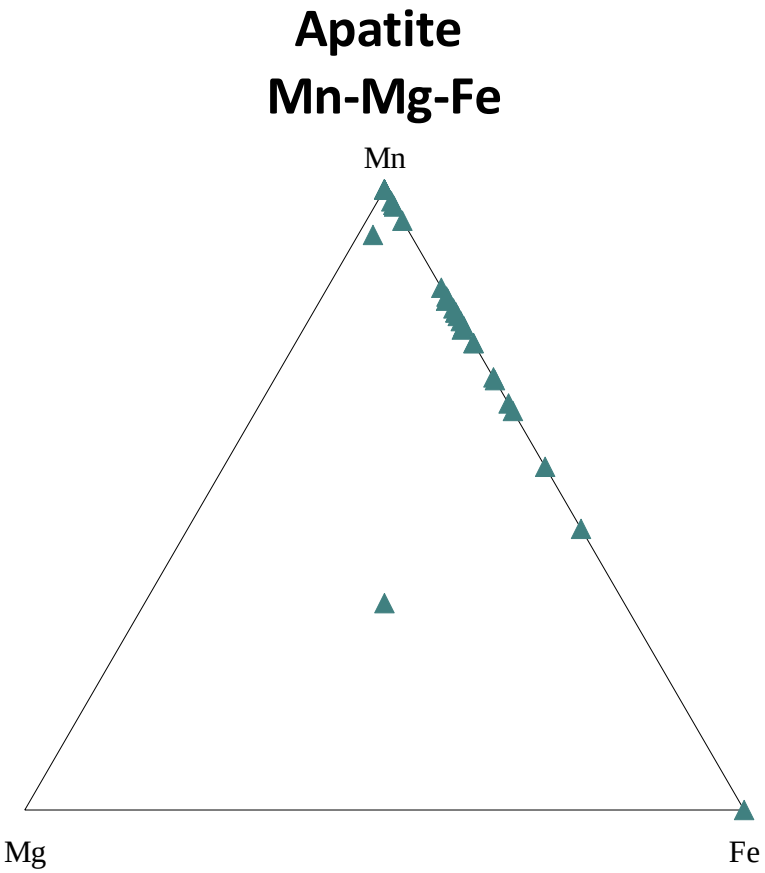


Figure 45: Mn-Fe-Mg ternary. Values of elements replacing Ca in the X-site.

Table 8. Representative Microprobe Analyses of Apatite from the Usakos Pegmatite.

Apatite from within Feldspars								
oxide	CZ1A2-1	CZ3B-3	CZ8-4	L3-7	U5-1	1.4-3	1.5-3	1.7-1
wt%	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
SiO_2	0.011	0.009	0.101	0.044	0.022	0	0.014	0
Al_2O_3	0	0.008	0.009	0	0.009	0.044	0	0.009
FeO	0.007	0.011	0.005	0.022	0	0.023	0.022	0.034
MgO	0	0	0	0	0	0.033	0	0
CaO	55.32	55.404	55.455	55.655	55.405	54.333	54.334	53.893
MnO	0.021	0.025	0	0.018	0.024	1.02	1.121	1.333
P_2O_5	42.144	41.988	42.543	42.366	42.008	41.611	42.091	42.22
F	3.455	3.31	3.009	2.982	3.292	3.092	3.112	3.093
H_20 calc.	0.298	0.364	0.525	0.534	0.373	0.454	0.458	0.4667
subtotal	101.256	101.119	101.647	101.621	101.133	100.610	101.152	101.049
F=O	1.455	1.394	1.267	1.256	1.386	1.302	1.310	1.302
Total	99.801	99.725	100.38	100.365	99.747	99.309	99.842	99.746
apfu								
Si	0.001	0.001	0.008	0.004	0.002	0	0.001	0
Al	0	0.001	0.001	0	0.001	0.004	0	0.001
Fe	0.001	0.001	0.000	0.002	0	0.002	0.002	0.002
Mg	0	0	0	0	0	0.004	0	0
Ca	4.972	4.987	4.945	4.972	4.985	4.923	4.891	4.852
Mn	0.002	0.002	0	0.001	0.002	0.073	0.08	0.095
P	2.993	2.986	2.998	2.991	2.987	2.98	2.9941	3.003
F	0.917	0.879	0.792	0.786	0.874	0.827	0.827	0.822
OH	0.167	0.204	0.291	0.297	0.209	0.256	0.257	0.261
x-site	4.975	4.991	4.955	4.978	4.989	5.007	4.973	4.949
y-site	2.993	2.986	2.998	2.991	2.986	2.976	2.994	3.003
z-site	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083

Table 8: Representative microprobe data of apatite from the Usakos pegmatite. Green columns primary apatite crystals. Gray columns apatite inclusions from within feldspar. Calculated on the basis of 12 oxygen.

Cassiterite

Figure 46: Cassiterite SnO_2 Dimensions: 3.9 cm x 2 cm x 2.9 cm (mindat.org)

Cassiterite was found in the intermediate areas of the pegmatite and within the lepidolite masses. Cassiterite bipyramids were found within the lepidolite masses (Fig. 47); in the intermediate areas cassiterite was anhedral. Accessory minerals associated with cassiterite found within the lepidolite mass include lepidolite, microlite, tantalite-(Mn), zircon, and apatite. Microprobe analysis was conducted on the cassiterite grains and representative analyses are presented in Table 9.

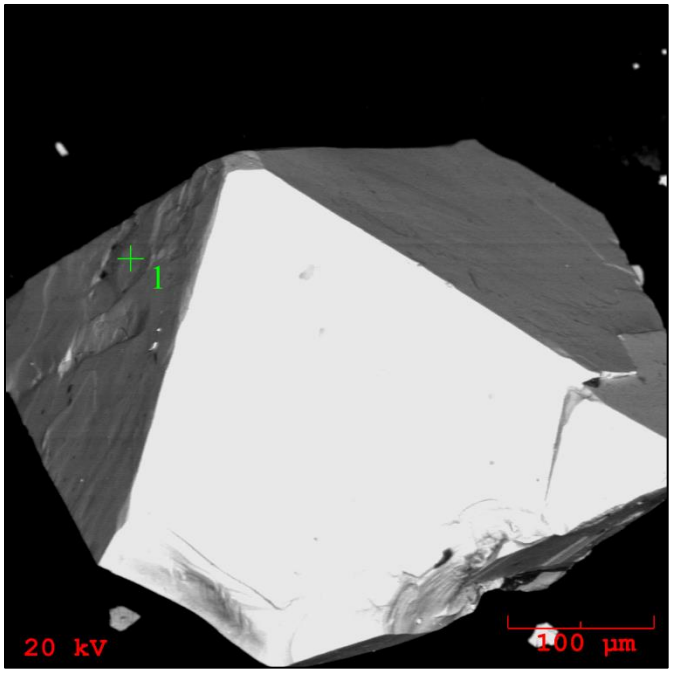


Figure 47: EDS backscattered image of cassiterite bipyramid

Table 9. Representative Microprobe Analyses of Cassiterite from the Usakos pegmatite.

	L2-1	L2-3	L2-4	L2-6-2	U-20-1	U-20-4
SnO_2	98.322	98.652	98.556	99.315	99.532	99.377
Ta_2O_5	0.892	0.723	0.744	0.315	0.234	0.125
Nb_2O_5	0.023	0.028	0.015	0.078	0.011	0.013
SiO_2	0	0	0	0	0.012	0.022
Al_2O_3	0	0.022	0	0	0	0
TiO_2	0	0	0	0	0	0
MnO	0.01	0.008	0.008	0.055	0.033	0.012
CaO	0	0	0	0	0.009	0
FeO	0.012	0.009	0.012	0.054	0.102	0.017
Total	99.259	99.442	99.335	99.817	99.933	99.566
apfu						
Sn	0.992	0.993	0.993	0.995	0.996	0.998
Ta	0.003	0.002	0.003	0.001	0.001	0.000
Nb	0.000	0.000	0	0.001	0	0
Si	0	0	0	0	0.000	0.001
Al	0	0.000	0	0	0	0
Ti	0	0	0	0	0	0
Mn	0.000	0.000	0.000	0.001	0.001	0.000
Ca	0	0	0	0	0.000	0
Fe	0.000	0.000	0.000	0.001	0.002	0.000

Table 9: Representative cassiterite microprobe analyses from the Usakos pegmatite calculated based on 2 oxygen.

Garnet

Figure 48: Garnet $X_3Z_2(SiO_4)_3$ Dimensions: 3.8 cm x 3 cm x 2.9 cm (mindat.org)

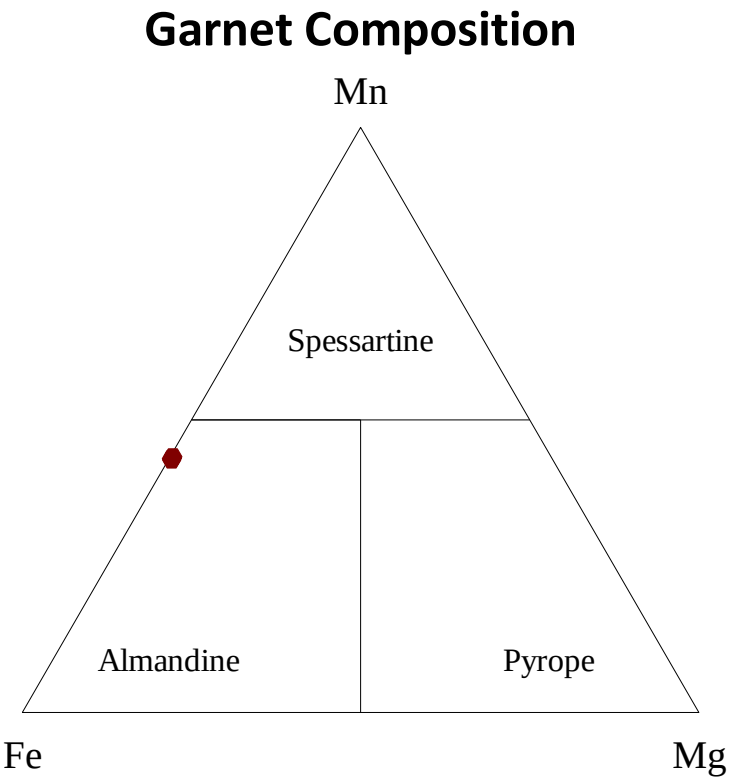


Figure 49: Garnet Classification Ternary with Usakos pegmatite garnet data.

Garnet was identified in one sample at the pegmatite-country rock contact. It occurred with large blades of biotite. Microprobe analysis was conducted and the results are presented in Table 10. The results are also plotted on the garnet classification ternary (Fig. 49).The garnet is classified as Almandine with Fe dominant in the X-site.

Table 10. Microprobe Analyses of Garnet from the Usakos Pegmatite.

	G1-1	G1-2	G1-3	G1-4	G1-5
oxide					
SiO_2	36.55	36.523	36.494	36.566	36.44
Al_2O_3	20.556	20.623	20.556	20.484	20.677
FeO	24.334	24.567	24.5	24.555	24.412
MnO	18.567	18.556	18.91	18.813	18.556
MgO	0.034	0.044	0.051	0.023	0.03
CaO	0.144	0.171	0.133	0.156	0.109
Total	100.185	100.484	100.644	100.597	100.224
apfu					
Si	3.01	3.002	2.999	3.005	3.001
Al	1.995	1.998	1.991	1.984	2.007
Fe	1.676	1.688	1.683	1.688	1.681
Mn	1.295	1.29	1.316	1.309	1.294
Mg	0.004	0.005	0.006	0.003	0.004
Ca	0.013	0.015	0.012	0.014	0.01
x-site	2.988	3.000	3.017	3.014	2.988
y-site	1.995	1.997	1.991	1.984	2.007
z-site	3.01	3.002	2.999	3.005	3.001

Table 10: Microprobe analyses of garnet from the Usakos pegmatite. a*pfu* calculated based on 12 oxygen.

Microlite

Figure 50: Microlite $(Ca,Na)_2Ta_2O_6(O,OH,F)$ Dimensions 1.5mm (mindat.org)

Microlite belongs to the pyrochlore super group of minerals and is classified as microlite because Nb+Ta ≥ 2Ti and Ta ≥ Nb (Hogarth 1977; Atencio *et al.* 2010). The microlite found at the Usakos pegmatite was confined to the lepidolite masses. It occurred with cassiterite, apatite, lepidolite, zircon, and both columbite and tantalite. Microprobe analysis was conducted on the microlite grains and the analyses are presented in Table 11. On the pyrochlore classification diagram most of the microlite population is close to the Ta end member (Fig. 51). There is a smaller population that contained some Ti enrichment. Based on the new nomenclature scheme for pyrochlore supergroup minerals, the microlite from the Usakos pegmatite is fluorcalciomicrolite (Atencio *et al.* 2010). Ca is dominant in the A-site and F is dominant at the Y-site. In addition, the samples displayed a range of Nb_2O_5 from 1.65 - 8.88 wt. % with an average of 5.19 wt. %.

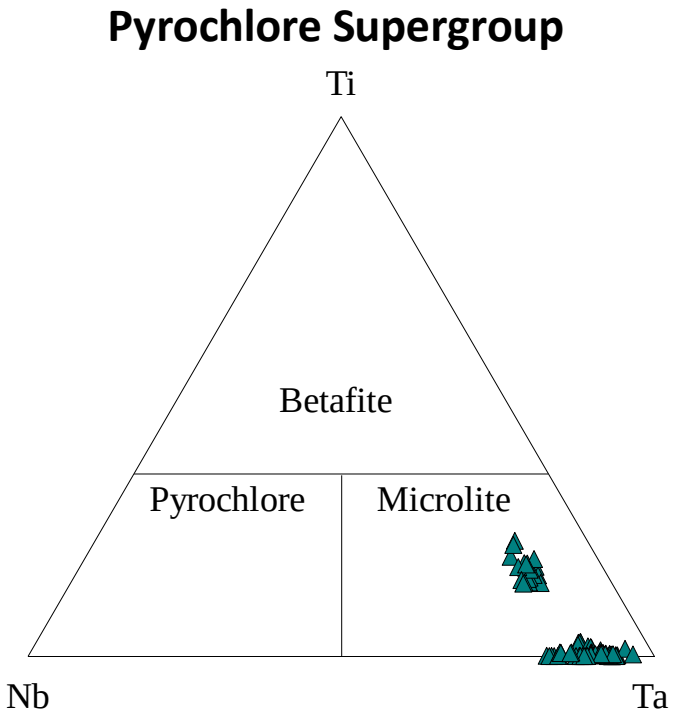


Figure 51: Pyrochlore super group classification ternary with Usakos pegmatite data.

Table 11. Representative Microprobe Analyses of Microlite from the Usakos Pegmatite.

	L1-1	L1-4	L1-2-1-3	L1-2-9-2	L1-5-1-1	L1-5-1-2	L1-5-1-3	L1-5-2-1
oxide								
Ta_2O_5	73.33	73.51	75.009	83.006	81.872	81.777	81.712	81.335
Nb_2O_5	5.54	5.45	4.722	2.096	3.556	3.612	3.634	3.89
CaO	12.99	12.78	12.559	10.335	11.091	10.891	10.43	10.101
Na_2O	2.56	2.67	2.393	1.897	2.112	1.871	2.043	1.943
TiO_2	0.78	0.75	0.532	0.455	0.012	0.023	0.018	0.02
Al_2O_3	0.02	0.07	0.031	0	0	0	0	0
FeO	0.28	0.22	0.112	0.177	0.043	0.026	0.026	0.026
MnO	0.43	0.42	0.223	0.334	0.101	0.084	0.093	0.077
SnO_2	0.02	0.04	0.092	0.033	0.022	0.015	0.017	0.022
WO_3	0.44	0.65	0.54	0.009	0	0.006	0	0
UO_2	0.37	0.33	0.088	0.008	0.009	0.008	0.011	0.014
Bi_2O_3	0	0	0.083	0.055	0.032	0.045	0.056	0.033
SiO_2	0.17	0.16	0.081	0.055	0.044	0.025	0.041	0.052
H2O(calc)	0.635	0.639	0.463	0.530	0.570	0.594	0.633	0.512
F	2.320	2.310	2.622	2.433	2.388	2.314	2.219	2.454
O=F	0.977	0.973	1.104	1.024	1.005	0.974	0.934	1.033
subtotal	99.885	99.999	99.550	101.423	101.852	101.291	100.933	100.479
Total	**98.908**	**99.027**	**98.446**	**100.399**	**100.847**	**100.317**	**99.998**	**99.446**
apfu								
Ta	1.724	1.728	1.792	2.010	1.959	1.970	1.977	1.979
Nb	0.217	0.213	0.188	0.084	0.141	0.145	0.146	0.157
Ca	1.203	1.183	1.182	0.986	1.046	1.034	0.994	0.968
Na	0.429	0.447	0.408	0.328	0.360	0.321	0.352	0.337
Ti	0.051	0.049	0.035	0.030	0.001	0.002	0.001	0.001
Al	0.002	0.007	0.003	0.000	0.000	0.000	0.000	0.000
Fe	0.020	0.016	0.008	0.013	0.003	0.002	0.002	0.002
Mn	0.031	0.031	0.017	0.025	0.008	0.006	0.007	0.006
Sn	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001
W	0.010	0.015	0.012	0.000	0.000	0.000	0.000	0.000
U	0.007	0.006	0.002	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.002	0.001	0.001	0.001	0.001	0.001
Si	0.015	0.014	0.007	0.005	0.004	0.002	0.004	0.005
OH	0.366	0.368	0.271	0.315	0.335	0.351	0.375	0.306
F	0.634	0.631	0.729	0.685	0.665	0.648	0.624	0.694

Table 11: Representative microprobe analyses of microlite from the Usakos pegmatite. Calculated based on 7 anions.

Columbite-Tantalite

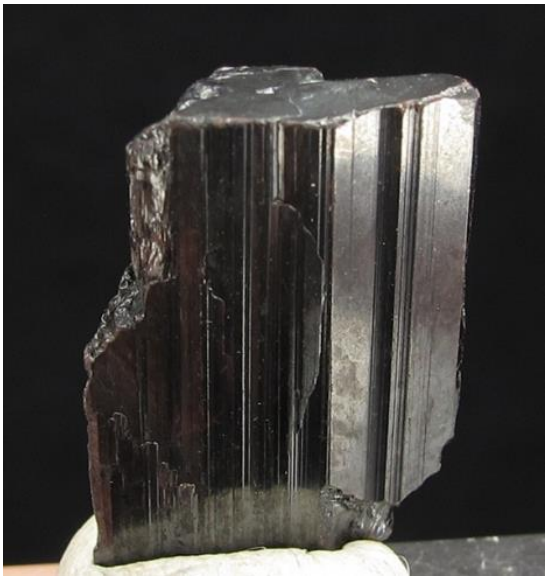


Figure 52: Tantalite – (Mn) $MnTa_2O_6$
Dimensions: 2.1 cm x 1.4 cm x 0.4 cm
(mindat.org)

Columbite-tantalite series minerals are important economic minerals that are associated with pegmatite deposits. Minerals from the columbite-tantalite series were identified at the pegmatite - country rock contact and in the core region of the Usakos pegmatite. At the pegmatite - country rock contact the species identified were columbite-(Fe) and within the core regions tantalite-(Mn) was identified. In addition, one sample analyzed was identified as tapiolite-(Fe) which is the tetragonal equivalent of tantalite-(Fe). Microprobe analysis was conducted on the microlite grains and the analyses are presented in Table 12. In addition, the analyses are plotted in the columbite-tantalite classification quadrilateral (Fig. 53) (Černý & Ercit 1989; Mackay & Simandl 2014).

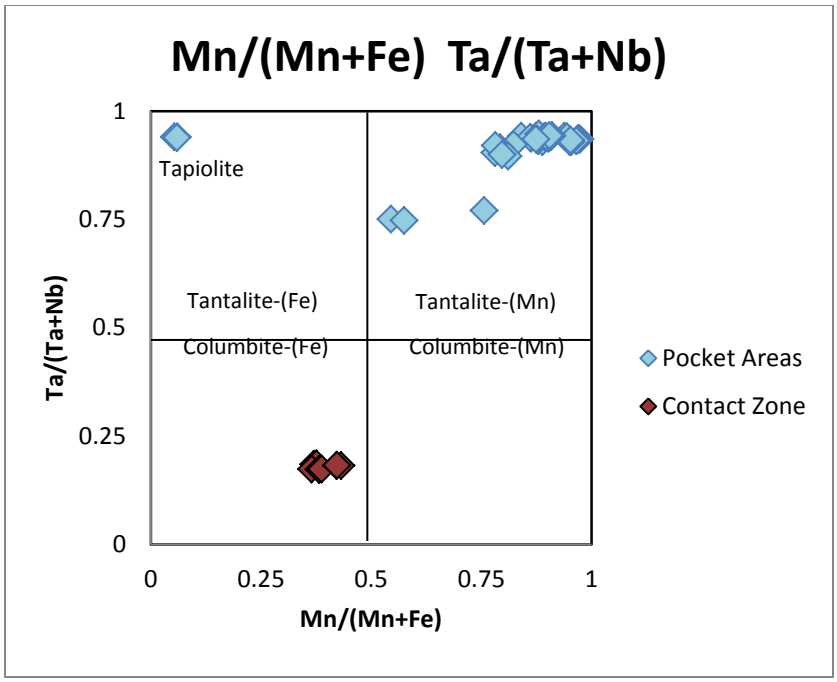


Figure 53: Columbite-Tantalite Classification Quadrilateral (Černý & Ercit 1989; Mackay & Simandl 2014)

Table 12. Representative Microprobe Analyses for the Columbite – Tantalite Series from the Usakos Pegmatite.

	CZ-1B-21-1	NT-2-1	NT3-2	L1-5-3-1	L1-10-7	L1-14-1	L1-14-br-2	L2-2-10	L2-5-3	L2-5-10
oxide										
Ta_2O_5	22.092	21.091	21.781	82.872	82.892	83.244	83.41	81.233	81.4	79.788
Nb_2O_5	58.77	60.223	58.98	3.765	3.334	3.112	3.023	4.53	4.23	5.334
CaO	0	0	0	0.045	0	0.012	0.009	0.044	0	0.009
Na_2O	0	0	0	0	0	0	0	0	0	0
TiO_2	0	0	0	0.017	0.022	0.011	0.009	0.013	0.009	0.015
Al_2O_3	0	0	0	0	0.013	0.009	0.023	0.042	0.025	0.011
FeO	12.009	12.52	11.234	1.505	1.891	1.44	1.21	2.982	3.12	3
MnO	7.123	7.11	8.43	11.871	11.778	11.981	12.155	11.237	11.045	11.651
SnO_2	0.011	0.008	0.013	0.022	0.041	0.011	0.019	0.036	0.022	0.023
WO_3	0.01	0.013	0.021	0	0.022	0	0	0	0	0
UO_2	0.011	0.021	0.009	0.013	0.023	0	0	0	0.012	0.037
Bi_2O_3	0	0	0	0	0.02	0	0	0.012	0.021	0.044
SiO_2	0.012	0.009	0.011	0.011	0.028	0.033	0.022	0.098	0.045	0.074
total	100.04	101	100.48	100.12	100.06	99.853	99.88	100.23	99.929	99.986
apfu										
Ta	0.37	0.348	0.362	1.877	1.882	1.898	1.902	1.822	1.838	1.786
Nb	1.634	1.651	1.632	0.142	0.126	0.118	0.115	0.17	0.159	0.198
Ca	0	0	0	0.004	0	0.001	0.001	0.004	0	0.001
Na	0	0	0	0	0	0	0	0	0	0
Ti	0	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	0	0	0	0	0.001	0.001	0.002	0.004	0.002	0.001
Fe	0.618	0.635	0.575	0.105	0.132	0.101	0.085	0.206	0.217	0.206
Mn	0.371	0.365	0.437	0.838	0.833	0.851	0.863	0.785	0.777	0.812
Sn	0.000	0.00	0.000	0.001	0.0014	0.000	0.001	0.001	0.001	0.001
W	0.000	0.000	0.000	0	0.001	0	0	0	0	0
U	0.000	0.00	0.000	0.000	0.000	0	0	0	0.00	0.001
Bi	0	0	0	0	0.000	0	0	0.000	0.001	0.001
Si	0.001	0.001	0.001	0.001	0.002	0.003	0.0018	0.008	0.004	0.006

Table 12: Representative microprobe analyses based on 6 oxygens. Pink columns correspond to columbite and the gray columns correspond to tantalite.

Montebrasite-Amblygonite

Figure 54: Montebrasite: LiAl(PO4)(OH)

Dimensions: 8 cm x 8 cm x 6 cm (mindat.org)

Both montebrasite and amblygonite were found in the core region of the Usakos pegmatite. Montebrasite and amblygonite form a solid solution series; montebrasite is OH dominant and amblygonite is F dominant (Fig. 55). A slab was cut, mounted and polished, then imaged and analyzed using the scanning electron microscope. Microprobe analysis was also conducted on the sample and the results are presented in Table 13. The montebrasite-amblygonite found was 3.5 cm in diameter and a milky gray color. Accessory minerals include schorlitic tourmaline, Li-muscovite, plagioclase, goyazite, and feldspar. The feldspar found as inclusions within the montebrasite contained high values of Cs_2O ranging between 7.21 wt% and 4.56 wt% with an average of 5.07 wt% (Table 13). Goyazite, a strontium bearing phosphate, was found as inclusions within the montebrasite (Figs. 56 & 57).

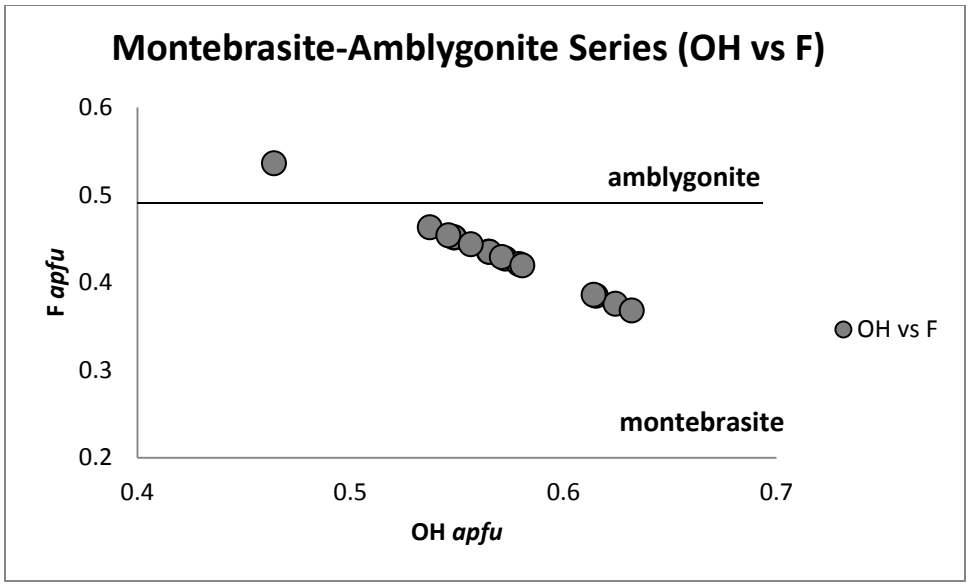


Figure 55: Plot- Montebrasite-Amblygonite Series (OH vs F)

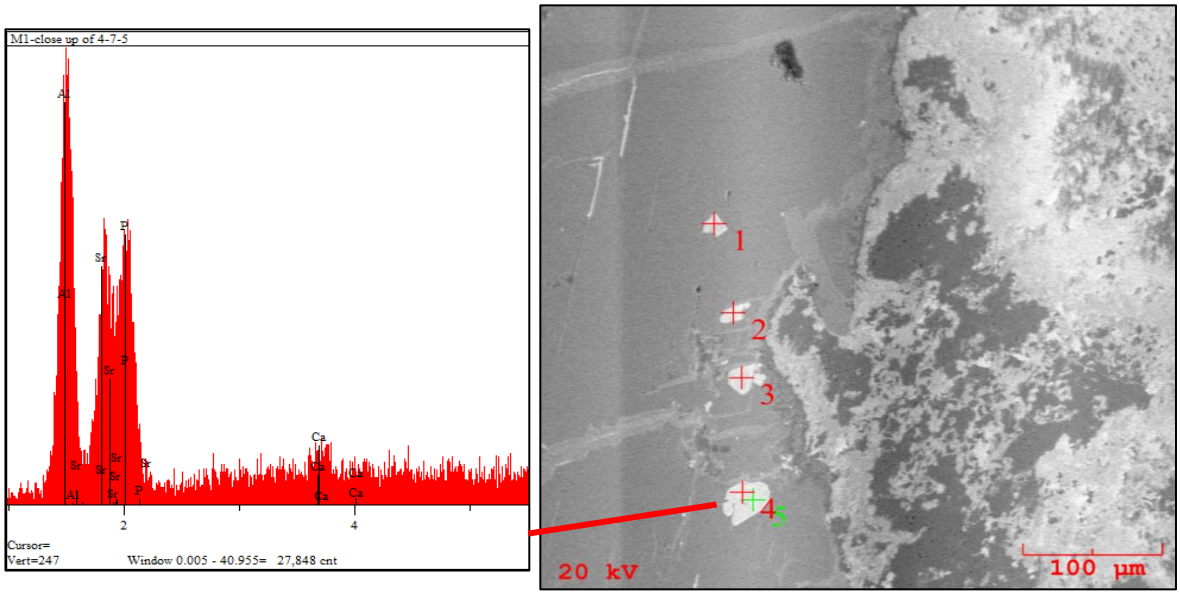


Figure 56: Backscattered image (left) and EDS spectra (right) of goyazite inclusions within the montebrasite-amblygonite.

Figure 57: Goyazite $SrAl_3(PO_4)_2(OH)_5{\cdot}H_2O$

Field of view 2.5mm (mindat.org)

Table 13.Representative Microprobe Analyses of Montebrasite-Amblygonite from the Usakos Pegmatite.

montebrasite-amblygonite Usakos 2-23-2014							
	M1-1	M5-2	M5-3	M7-1	M7-2	M8-1	M8-3
CaO	0.022	0.014	0.017	0	0.008	0.012	0.019
MnO	0.008	0	0	0	0.009	0	0
FeO	0.007	0	0	0	0	0.007	0
Al_2O_3	34.788	34.784	34.764	34.674	34.585	34.588	34.558
P_2O_5	48.711	48.667	48.575	48.625	48.559	48.585	48.63
SiO_2	0.091	0.018	0.016	0	0.012	0.009	0.011
K_2O	0.022	0.012	0.023	0.02	0.023	0.017	0.013
Na_2O	0.098	0.078	0.073	0.062	0.082	0.081	0.056
F	5.011	4.784	5.009	5.643	5.558	5.884	5.75
SrO	0.009	0.023	0.022	0.024	0.033	0.023	0.028
BaO	0.000	0.008	0	0.009	0.008	0.013	0.012
Li2O	10.184	10.177	10.161	10.165	10.133	10.139	10.155
H2O	3.802	3.900	3.785	3.480	3.511	3.358	3.424
subtotal	102.753	102.465	102.445	102.703	102.521	102.717	102.655
O=F	2.110	2.014	2.109	2.376	2.340	2.477	2.421
total	**100.643**	**100.451**	**100.336**	**100.327**	**100.181**	**100.239**	**100.234**
apfu							
Ca	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.995	0.997	0.997	0.995	0.994	0.994	0.993
P	1.001	1.002	1.001	1.003	1.003	1.003	1.004
Si	0.002	0.000	0.000	0.000	0.000	0.000	0.000
K	0.001	0.000	0.001	0.001	0.001	0.001	0.000
Na	0.005	0.004	0.003	0.003	0.004	0.004	0.003
F	0.385	0.368	0.386	0.435	0.429	0.454	0.443
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Li	0.994	0.995	0.995	0.996	0.994	0.994	0.996
OH	0.615	0.632	0.614	0.565	0.571	0.546	0.557
v-site	1.000	1.000	1.000	1.000	1.000	1.000	1.000
x-site	0.997	0.997	0.998	0.995	0.995	0.994	0.993
y-site	1.001	1.002	1.001	1.003	1.003	1.003	1.004
z-site	1.000	1.000	1.000	1.000	1.000	1.000	1.000
F	0.385	0.368	0.386	0.435	0.429	0.454	0.443
OH	0.615	0.632	0.614	0.565	0.571	0.546	0.557

Table 13: Representative microprobe analyses of montebrasite-amblygonite. Calculated based on 5 anions. Amblygonite column: dark blue; montebrasite columns light blue

Zircon

Figure 58: Zircon : $ZrSiO_4$

Dimensions: 20mm x 19mm x 19m (mindat.org)

Zircon grains were identified only in the lepidolite masses of the Usakos pegmatite. The zircon grains are yellow to orange in color, and was found in association with cassiterite, apatite, lepidolite, microlite, and tantalite-(Mn). Microprobe analysis was conducted on the zircon grains and the analyses are presented in Table 14. The zircon samples contained high weight percent of HfO_2 ranging from 3.68 wt. % to 6.78 wt. % with an average of 5.51 wt. %. The Hf-Th-U ternary displays the relative enrichment of Hf over Th and U (Fig. 60). In addition, most of the zircon grains had a secondary overgrowth of zircon on the rim. The chemistry of the secondary zircon rim was more highly evolved than the core of the crystal. On the Zr/Hf vs HfO_2 plot the average composition of zircon cores and rims is plotted (Fig. 59). The zircon rims exhibit a Zr/Hf ratio that is lower and the HfO_2 concentration is higher than the zircon core, which is indicative of a higher degree of evolution. This secondary stage of zircon crystallization is interpreted as some of the latest stage of fluid evolution.

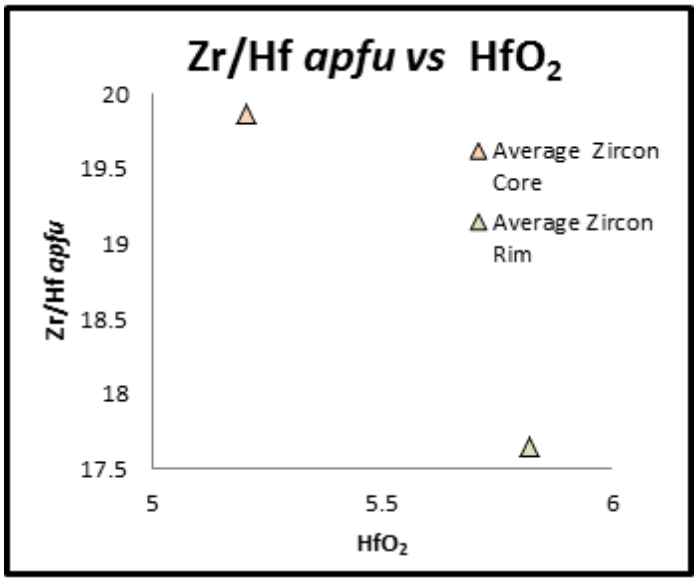


Figure 59: Zr/Hf *apfu vs* HfO_2 for zircon.

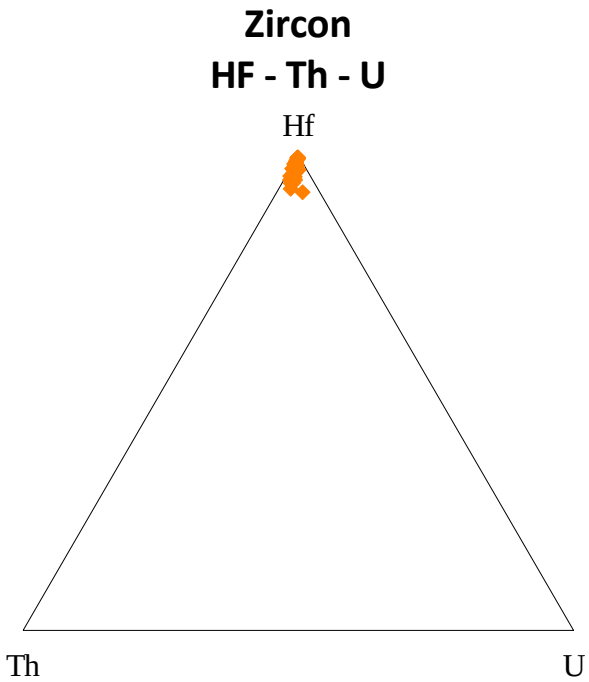


Figure 60: Hf-Th-U ternary for all zircon.

Table 14. Representative Microprobe Analyses of Zircon from the Usakos Pegmatite.

	L3-1-core	L3-1-rim	L3-9-3 core	L3-9-3 rim	L3-10-3 core	L3-10-3 rim	L3-13-1 core	L3-13-1 rim
oxide								
ZrO_2	59.655	58.874	59.788	59.55	60.022	59.777	59.956	59.65
SiO_2	31.555	31.091	31.555	31.235	31.671	31.224	31.588	31.444
HfO_2	5.778	6.76	5.76	5.98	5.383	5.887	5.455	5.76
UO_2	0.123	0.045	0.045	0.032	0.11	0.089	0.056	0.033
FeO	0.289	0.213	0.445	0.423	0.211	0.191	0.345	0.282
CaO	1.23	1.091	0.777	0.803	0.433	0.413	0.445	0.243
Al_2O_3	0.022	0.043	0.019	0.043	0.022	0.009	0.022	0.012
MnO	0.121	0.346	0.093	0.033	0.033	0.028	0.112	0.082
TiO_2	0.22	0.114	0.032	0.026	0.016	0.019	0.033	0.028
ThO_2	0.114	0.212	0.112	0.092	0.222	0.322	0.155	0.101
Total	99.107	98.789	98.626	98.217	98.123	97.959	98.167	97.635
apfu								
Zr	0.918	0.915	0.924	0.926	0.930	0.933	0.93	0.930
Si	0.996	0.991	1.001	0.997	1.007	1.000	1.004	1.006
Hf	0.052	0.062	0.052	0.055	0.049	0.054	0.05	0.053
U	0.001	0.000	0.000	0.000	0.001	0.001	0.000	0.000
Fe	0.008	0.006	0.012	0.011	0.006	0.005	0.009	0.008
Ca	0.042	0.037	0.026	0.027	0.015	0.014	0.015	0.008
Al	0.000	0.001	0.000	0.001	0.00	0.000	0.000	0.000
Mn	0.003	0.009	0.003	0.001	0.001	0.001	0.003	0.002
Ti	0.005	0.003	0.001	0.001	0.00	0.001	0.001	0.001
Th	0.001	0.002	0.001	0.001	0.002	0.002	0.001	0.001
x-site	1.03	1.034	1.019	1.022	1.003	1.010	1.009	1.003
y-site	0.997	0.992	1.001	0.997	1.007	1.000	1.005	1.006

Table 14: Microprobe data from Usakos pegmatite zircons. Calculated on the basis of 4 oxygen.

Whole Rock Geochemistry

Whole Rock Data

Whole Rock Data:

Whole rock data was obtained from samples collected close to the country rock and pegmatite contact. As was discussed above, it is unreasonable to gather accurate whole rock data representative of the entire pegmatite due to the innate heterogeneity of pegmatites. For this reason we use a 'wall zone' analogue which has been interpreted to be the most representative area possible for gathering whole rock data for the pegmatite. The 'wall zone' analogue is the most expressive of the whole pegmatite because it is the first portion of the pegmatitic melt to crystalize and therefore has not undergone much fractionation.

For whole rock data analysis, six samples from the country rock – pegmatite contact were collected as well as one sample of the country rock. The samples were analyzed via ICP to gather data on 10 major and 45 minor elements. The results from those analyses are presented in Table 15.

There are several diagrams used to classify rocks based on major element composition. The Total Alkali-Silica diagram (TAS) is used to classify igneous rocks based on the silica content versus the alkali content. The whole rock samples taken from within the pegmatite are granitic in composition with a relatively low total alkali content in the TAS diagram (Fig. 61). The sample gathered from the country rock is a metasedimentary rock and therefore is not represented in the TAS diagram for igneous rocks.

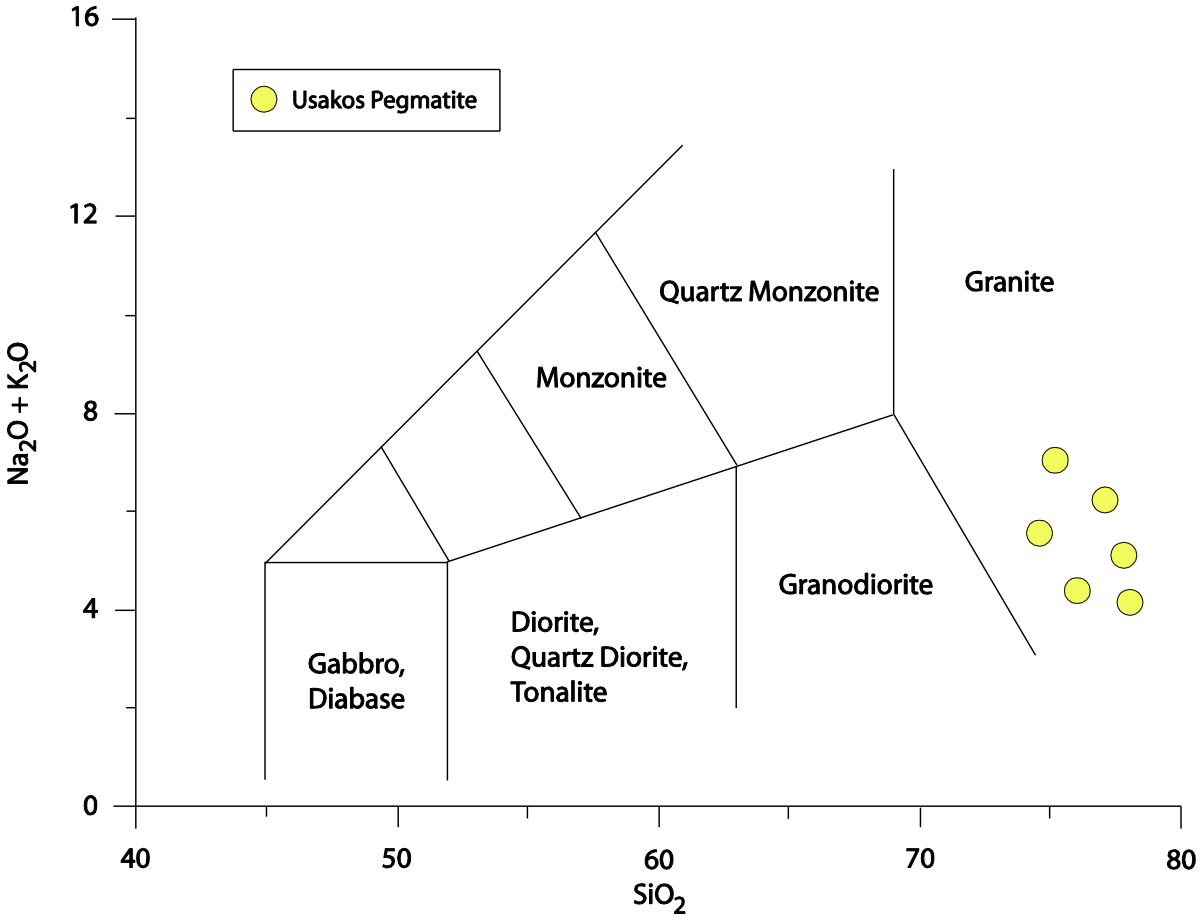


Figure 61: Igneous rock type classification based on the total alkali vs silica content for wall zone analogue samples from the Usakos pegmatite (Bateman et al. 1989).

The Shand index, further classifies granitic rocks into metaluminous, peraluminous, and peralkaline using the molar ratio of Al/(Na+K) vs Al/(Ca+Na+K) to depict the aluminum saturation index (ASI) for high silica rocks (Maniar & Piccoli 1989). Both the samples from the Usakos pegmatite, and the hosting country rock, plot in the peraluminous field (Fig. 62).

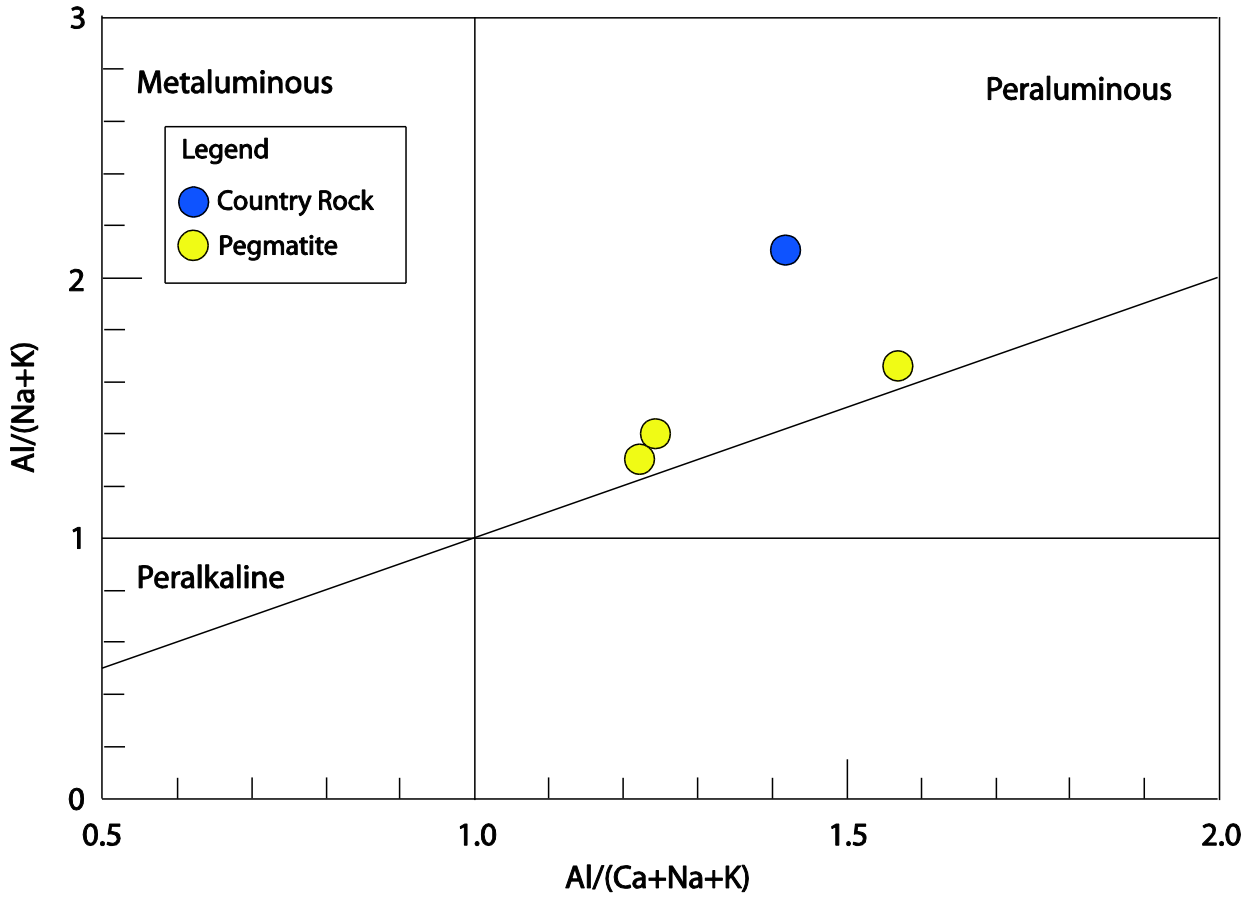


Figure 62: Shand index. Display of Al saturation in the whole rock samples from the Usakos pegmatite and hosting country rock.

Tectonic Interpretation of the Usakos Pegmatite

Traditionally, trace element discrimination diagrams have been used to interpret the tectonic setting of volcanic rocks. Granites can be difficult to attribute to a certain tectonic setting due to the time lag from genesis to exposure and their complicated petrogenetic history. Pearce *et al.* (1984) extended the use of trace element discrimination diagrams for use in interpreting the tectonic setting of granitic rocks. There is a wide variety of potential tectonic settings in which granites can form for example: syn-collisional (Syn-COLG), within plate (WPG), volcanic arc (VAG), and mid-ocean ridge granites (ORG). To distinguish between these tectonic settings trace element data was plotted in a series of tectonic discrimination diagrams (Figs. 50-52).

The Usakos pegmatite can be classified as syn-collisional with some points plotting on the margins (Figs. 63-65). In Pearce *et al.* (1984) the complexity relating to using tectonic distinction diagrams for post-tectonic collisional diagrams is described. On the Rb ppm *vs* Y + Nb ppm diagram some fields for known post-collision granites have been plotted shown in gray (Pearce *et al.* 1984) (Fig 63). The Usakos pegmatite plots close to these fields and is interpreted to be late- tectonic in origin but still related to collisional tectonics.

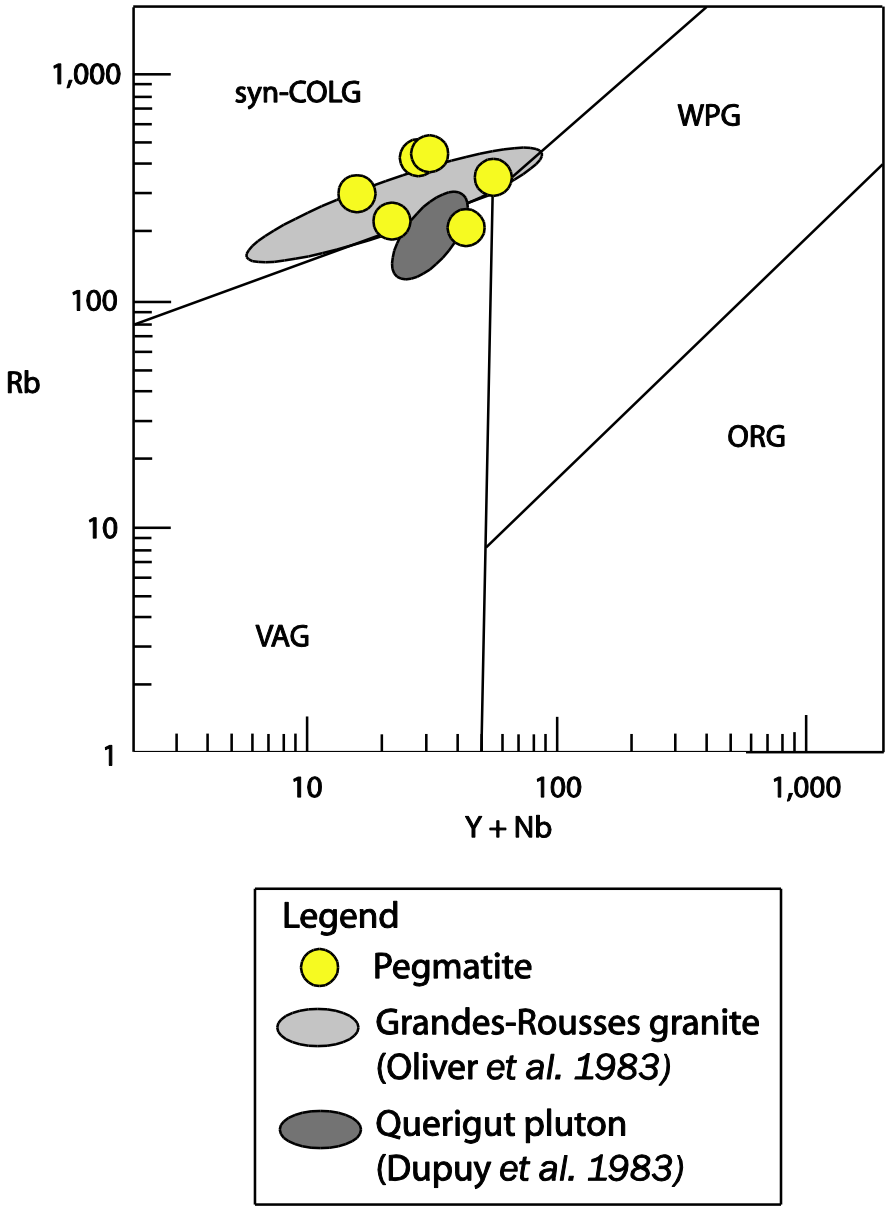


Figure 63: Rb *vs* Y + Nb tectonic distinction diagram for Usakos pegmatite whole rock data (Pearce *et al.* 1984).

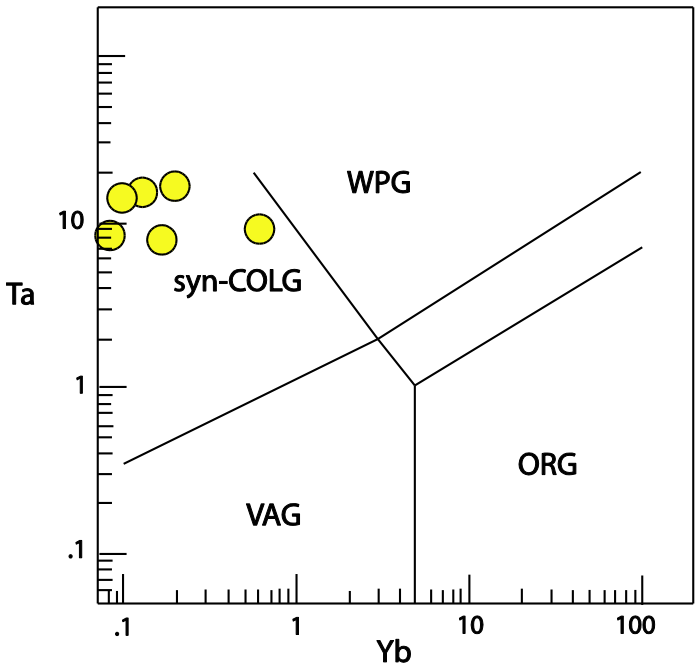


Figure 64: Ta *vs* Yb tectonic distinction diagram for Usakos pegmatite whole rock data (Pearce *et al.* 1984).

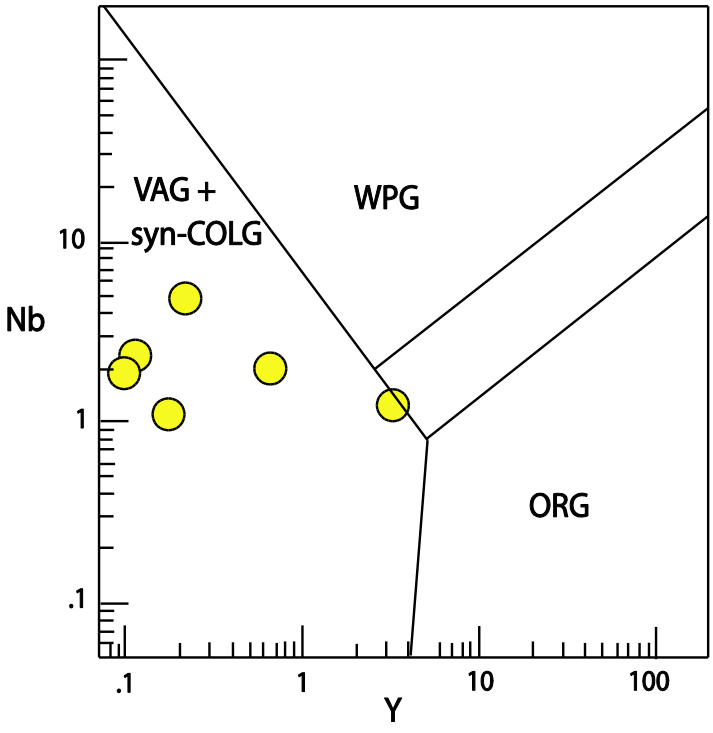


Figure 65: Nb *vs* Y tectonic distinction diagram for Usakos pegmatite whole rock data (Pearce *et al.* 1984).

Table 15. Whole Rock Data from ICP-OES-MS.

Sample	CZ-1A	CZ-1B	CZ-5	CZ-7	CZ-8	CZ-6	CR-1
wt%							
SiO_2	76.51	78.29	77.94	77.33	75.37	74.85	60.47
Al_2O_3	14.9	13.65	12.55	14.29	14.4	16.31	16.48
Fe_2O_3(T)	0.61	1.37	0.53	0.46	0.48	0.68	7.05
MnO	0.024	0.107	0.022	0.033	0.032	0.01	0.143
MgO	0.18	0.2	0.1	0.08	0.1	0.15	3.63
CaO	0.84	0.41	0.76	0.57	0.47	0.23	2.09
Na_2O	0.34	1.29	3.07	5	0.87	0.89	1.97
K_2O	4.02	2.77	2.8	1.57	6.01	4.99	3.7
TiO_2	0.025	0.039	0.018	0.016	0.026	0.032	0.746
P_2O_5	0.49	0.24	0.36	0.36	0.4	0.21	0.13
LOI	2.61	1.8	1.73	0.96	1.79	2.14	2.1
Total	**100.5**	**100.2**	**99.87**	**100.7**	**99.93**	**100.5**	**98.51**

Sample		CZ-1A	CZ-1B	CZ-5	CZ-7	CZ-8	CZ-6	CR-1
ppm	**Det. Limit**							
Sc	1	3	4	2	3	2	3	15
Be	1	3	5	4	4	4	4	3
V	5	7	bdl	5	6	8	6	109
Cr	20	bdl	bdl	bdl	bdl	bdl	bdl	80
Co	1	bdl	bdl	bdl	bdl	1	bdl	19
Ni	20	bdl	bdl	bdl	bdl	bdl	bdl	40
Cu	10	bdl	bdl	bdl	bdl	20	bdl	30
Zn	30	bdl	70	40	bdl	130	40	130
Ga	1	33	31	19	24	22	29	22
Ge	0.5	3.3	3.9	3.5	4	4	3.2	2.2
As	5	bdl	bdl	bdl	bdl	11	bdl	bdl
Rb	1	458	345	284	192	429	422	172
Sr	**2**	**10**	**13**	**30**	**11**	**35**	**25**	**123**
Y	0.5	1.2	2.3	1.8	1.1	6.2	1.1	29.4
Zr	1	7	11	8	5	19	4	186
Nb	0.2	51.9	54.9	13.3	22.3	21.5	27.7	15.5
Mo	2	bdl	bdl	bdl	bdl	2	bdl	bdl
Ag	0.5	bdl	bdl	bdl	bdl	bdl	bdl	0.9
In	0.1	0.1	0.1	bdl	bdl	bdl	0.1	bdl
Sn	1	60	50	37	24	48	45	4
Sb	0.2	0.3	0.3	bdl	0.2	0.7	bdl	bdl
Cs	0.1	10.7	8.6	12.2	7	14.6	14.9	19.9
Ba	3	132	30	24	26	142	32	478

La	0.05	0.67	0.83	0.75	0.7	3.93	0.38	49.7
Ce	0.05	1.14	1.61	1.23	1.19	7.63	0.66	102
Pr	0.01	0.12	0.17	0.13	0.11	0.84	0.07	11.1
Nd	0.05	0.36	0.61	0.41	0.34	3.05	0.19	41.8
Sm	0.01	0.13	0.21	0.16	0.18	0.78	0.11	8.54
Eu	0.005	0.259	0.044	0.05	0.054	0.242	0.044	1.45
Gd	0.01	0.14	0.27	0.2	0.13	0.89	0.15	6.2
Tb	0.01	0.04	0.07	0.05	0.04	0.19	0.04	1.01
Dy	0.01	0.27	0.44	0.32	0.22	1.32	0.22	6.14
Ho	0.01	0.05	0.08	0.06	0.03	0.24	0.04	1.17
Er	0.01	0.12	0.21	0.15	0.09	0.62	0.11	3.34
Tm	0.005	0.018	0.03	0.022	0.013	0.09	0.016	0.489
Yb	0.01	0.13	0.21	0.16	0.09	0.64	0.1	3.12
Lu	0.002	0.027	0.047	0.031	0.016	0.121	0.017	0.496
Hf	0.1	0.5	0.6	0.3	0.2	0.7	0.1	4.9
Ta	0.01	15.7	15.6	7.84	8.49	9.16	13.8	1.28
W	0.5	36.9	30	9.7	11.8	21.3	26.5	1.9
Tl	0.05	1.48	1.38	1.46	1.01	2.21	2.6	1.38
Pb	5	7	17	15	16	84	15	21
Bi	0.1	0.8	19.6	0.2	0.4	0.2	0.5	0.3
Th	0.05	0.64	0.91	0.37	0.48	1.73	0.38	15.6
U	0.01	4.4	6.19	2.16	1.81	4.44	0.89	3.52

Table 15: Whole Rock Data ICP-OES-MS

Spider Diagrams

The following section displays and discusses whole rock data from the Usakos pegmatite compared with several idealized rock types. The first diagram (Fig. 66) is the chondrite normalized rare-earth-element (REE) + Y spider diagram (Sun & McDonough 1989). This spider diagram specifically compares REE values of the analyzed rock with values of a chondrite. A chondrite is a meteorite which has not been modified due to melting or fractionation processes, and is representative of the most primitive undifferentiated bulk earth composition. The second diagram (Fig. 67) is an upper continental crust normalized spider diagram (Rudnick –Fountain 1995 & Taylor –McLennan 1985). In this diagram a range of major, trace, and REEs are used as a comparative basis. The third diagram (Fig. 68) in this section is the mid ocean ridge normalized spider diagram (Sun & McDonough 1989). This diagram also illustrates similarities and differences of a range of major, trace and REEs. In all of the diagrams there are distinct geochemical trends that link the Usakos pegmatite data together.

In the chondrite-normalized REE+Y diagram (Fig. 66) the overall signature of the Usakos pegmatite is very similar with two standout exceptions. Sample CZ8 has a higher overall enrichment than any of the other samples. This sample was composed of finer-grained material than the other samples and therefore a better representation of the pegmatites' overall signature. The second exception is the large positive Eu anomaly in sample CZ 1A. This large positive Eu anomaly is related to abundant feldspar in the sample. Eu is the only lanthanide series REE that is compatible in feldspar. In addition, the Usakos pegmatite exhibits slight enrichments in La and Ce. The trend flattens out and is relatively unenriched or depleted with

respect to the rest of the REE's with an exception of a slight enrichment in the last heavy-REE Lu.

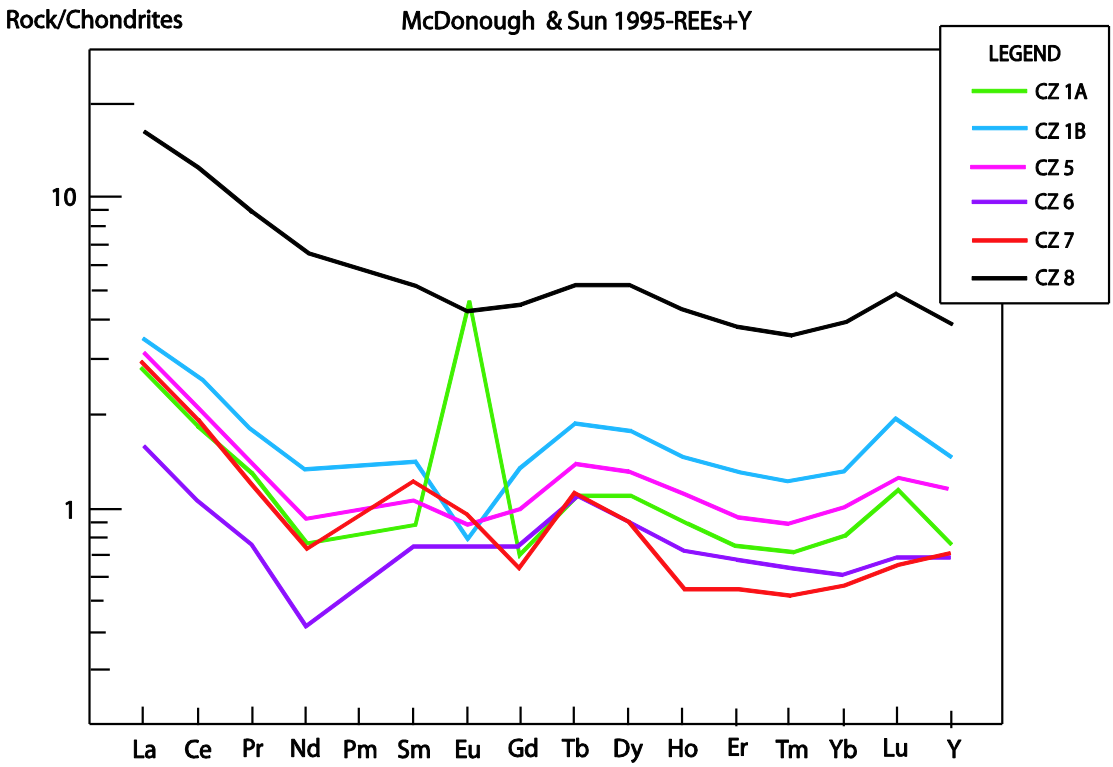


Figure 66: Whole rock chondrite normalized REE diagram. Display of relative REE enrichments and depletions for the Usakos whole rock data (Sun & McDonough 1989)

The geochemical trend of the Usakos pegmatite in the upper continental crust-normalized spider diagram (Fig. 67) exhibits some enrichments and depletions which is evidence of geochemical evolution of the parental magma from which the pegmatite was derived (Taylor & McLennan 1985; Rudnick & Fountain 1995). There is an enrichment in the alkali elements which is expected in pegmatites. There is a greater abundance of Ta *vs* Nb, this is expected in an LCT pegmatite. The peaks at Pb and U are interpreted to be related to

radiogenic Pb. The Usakos pegmatite is depleted in all REEs when compared to upper continental crust. This depletion is more pronounced in the LREEs than in the HREEs.

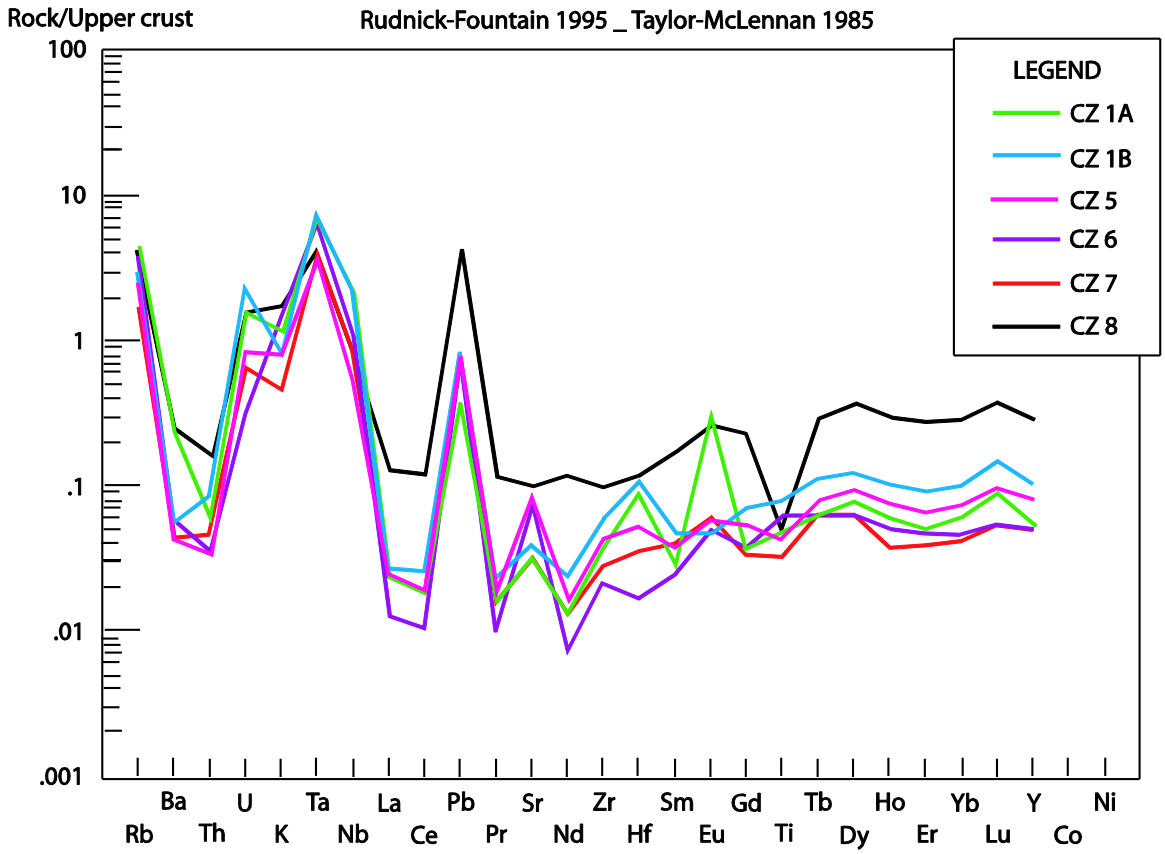


Figure 67: Whole rock upper continental crust-normalized spider diagram depicting the elemental enrichments and depletions of the Usakos pegmatite whole rock data (Taylor & McLennan 1985; Rudnick & Fountain 1995)

The mid ocean ridge basalt-normalized spider diagram (Fig. 68) exhibits much of the same information depicted in the first two diagrams of this section. The key difference is the addition of the element Cs to the plot. The Usakos pegmatite has the highest enrichment of Cs relative to any of the other elements in this diagram. It is interesting to note that some of the feldspar analyzed having several weight percent of Cs_2O present.

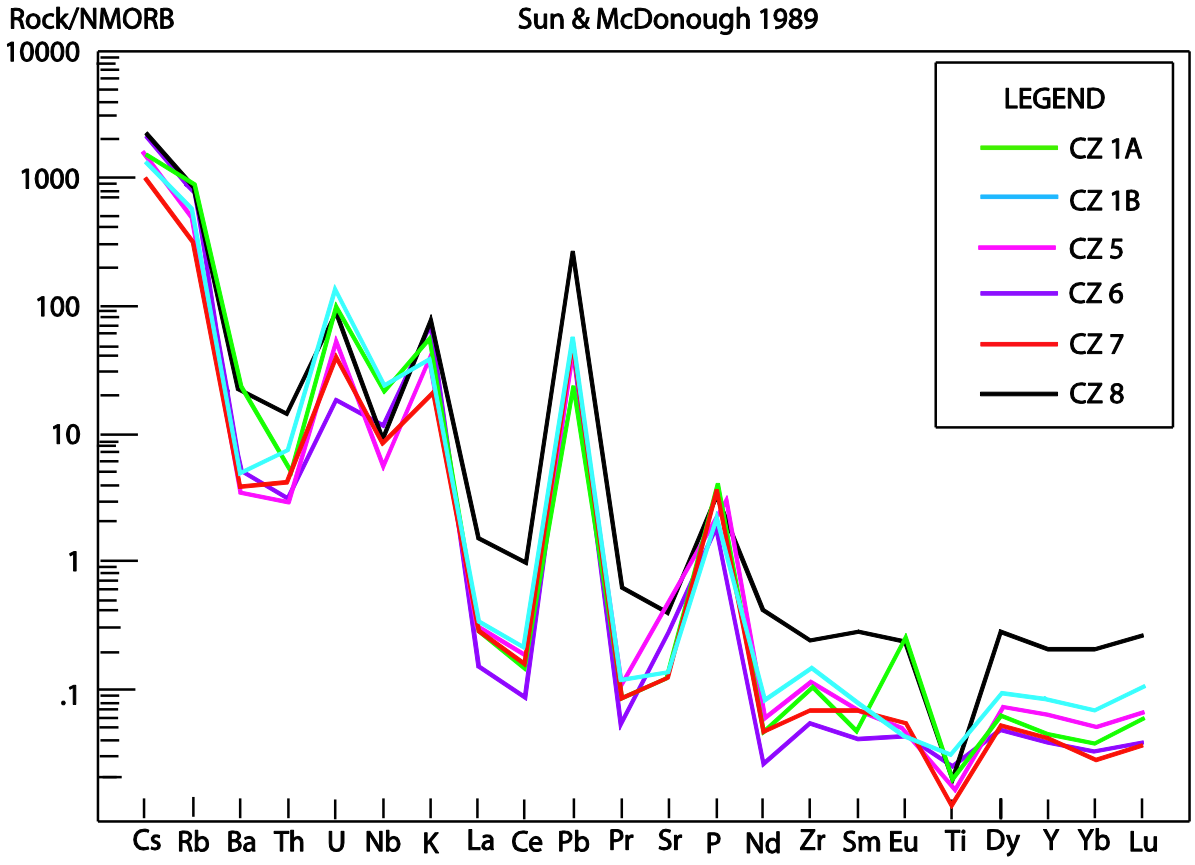


Figure 68: Whole rock mid ocean ridge basalt-normalized spider diagram depicting elemental enrichments and depletions of the Usakos whole rock data (Sun & McDonough 1989).

Conclusions

The aims of this study were to complete a thorough mineralogical and geochemical investigation of an economically important pegmatite within the Usakos – Karibib pegmatite belt and relate those findings to the petrogenic evolution of the pegmatite. To complete the geochemical evaluation of the Usakos pegmatite samples were collected from several areas within the pegmatite: the country rock - pegmatite contact, intermediate areas, and the core region in and around pockets.

The Usakos pegmatite, located in west central Namibia, is a highly evolved, Rare-Element LCT- family pegmatite. The pegmatite is spatially related to the Usakos-Karibib pegmatite belt as defined by Keller (1999) although it is located just north west of that field. The pegmatite was emplaced into metasedimentary rocks of the Kuiseb formation in the SCZ of the Damara belt; and is temporally related to the late- tectonic evolution of the Damaran Orogen.

The samples taken from the country rock-pegmatite contact show evidence of metosomatic exomorphism. The country rock samples taken 25 cm away from the pegmatite have no boron mineralization present whereas, samples taken from where the country rock and the pegmatite are in contact have extensive boron mineralization in the form of tourmaline. In addition some strontium mineralization is also present in the more evolved portions of the pegmatite. This strontium enrichment, in the form of goyazite grains, is interpreted to be sourced from interaction between the pegmatitic melt and the hosting country rock.

Further evidence for interaction between the pegmatite melt and the country rock is the abundance of Ca mineralization close to the pegmatite – country rock contact in the form of primary apatite. Perhaps one of the strongest lines of evidence for the interaction between the pegmatite melt and the host rock is a phase of tourmaline crystallization close to the contact. In this phase the tourmaline is enriched in Al, so much so that it plots in the elbaite field of the tourmaline classification diagram (Fig. 31).

The Usakos pegmatite is interpreted to be a highly evolved pegmatite, which exhibits classic trends of internal pegmatite evolution. The K/Rb ratios from the Li-micas range from an average of 97 at the contact to an average of 17 in the core areas of the pegmatite. The K/Rb ratios for the feldspars show the same fractionation trend from high at the contact to low in the core regions. In addition, the Cs content of the micas and the feldspar follow a similar trend, although not overly abundant, Cs does increase from the contact to the core.

The tourmaline from the Usakos pegmatite has a range in composition from schorl to elbaite. As discussed above, tourmaline crystallization underwent an initial phase early in the formation of the pegmatite where abundant Al from country rock interaction was available. Tourmaline crystallization then experienced a hiatus until the melt accumulated sufficient B and H_2O saturation to continue. In this renewed phase of tourmaline crystallization, there is a clear fractionation trend from Fe-rich schorl to Fe-depleted and Li-enriched elbaite from the intermediate areas of the pegmatite to the core. In addition, there is a strong correlation between the color and chemical composition of the tourmaline. The darker tourmalines are

more enriched in Fe whereas the lighter to colorless tourmalines are more enriched in Li and X-site Vacancies.

From the columbite-tantalite group, both columbite-(Fe) and tantalite-(Mn) were identified. At the contact the less evolved columbite-(Fe) was present whereas in the core regions the highly evolved tantalite-(Mn) species was present.

Microlite identified in the core region of the pegmatite presents a complication associated with late stage Ca. The origin of this late Ca is uncertain and could be related to processes that are not well understood such as complexing between an anion or radical and Ca. This process could retain Ca and introduce it in late stage Ca bearing assemblages.

Whole rock geochemistry data for the Usakos pegmatite was used to determine that the pegmatite is late-tectonic in origin. It should be emphasized that the Usakos pegmatite cannot be related to a parental granitic body as is the case with other economic pegmatites of the region. The collisional environment that this pegmatite was derived from may have produced enough heat to have formed the pegmatite by anatectic processes. Trace element geochemistry indicates an overall enrichment in light rare earth, with slight Eu depletions with the exception of a positive Eu anomaly in one plagioclase rich sample. Spider diagrams relative to MORB and upper crust show enrichments in Rb, Cs Ta>Nb and P enrichment which is consistent with the LCT nature of the pegmatite. The Usakos pegmatite has a pattern of enrichments and depletions relative to other rock types that are interpreted as evidence that the forming pegmatite melt was geochemically evolved.

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Appendix A: Microprobe Analyses

Microprobe analyses of all tourmaline samples.

Standards for EMP analyses for **tourmaline** Acceleration potential: 15 Kv Beam current: 15 nA Beam width: 2 microns Count times: 45 seconds per spot	
Adularia, Fibbia	K
Albite, Tiburon	Na
Andalusite, Minas Gerias	Al, Si
$Bi_4Ge_3O_{12}$, synthetic	Bi
Chromite, Stillwater MT	Cr
Clinopyroxene, "Cpx-26-ano"	Fe,Mg,Ca,Ti
Fluortopaz, Thomas Range, UT	F
PbO, synthetic	Pb
Rhodonite, Broken Hill	Mn
TiO_2, synthetic	Ti
V_2O_5, synthetic	V
ZnO, synthetic	Zn
Other MAN standards used: Al_2O_3, synthetic Hematite, Elba MgO, synthetic PbO, synthetic V_2O_5, synthetic ZnO, synthetic ZrO_2, synthetic	

All tourmaline analyses are calculated based on 31 anions.

Sample	CT.1-1	CT.1-2	CT.8-1	CT.8-2
SiO_2	37.633	37.549	37.763	37.623
TiO_2	0.000	0.000	0.000	0.009
B_2O_3 calc.	11.103	11.098	11.106	10.977
Al_2O_3	42.189	42.114	42.009	40.694
FeO	0.132	0.323	0.167	1.271
MnO	0.386	0.455	0.412	0.488
CaO	0.422	0.451	0.073	0.095
ZnO	0.009	0.008	0.000	0.009
Li_2O calc.	1.993	1.969	2.008	1.906
Na_2O	1.814	1.844	2.200	2.184
K_2O	0.019	0.009	0.044	0.019
H_2O calc.	3.309	3.352	3.283	3.237
F	1.100	1.006	1.158	1.162
Subtotal	**100.109**	**100.178**	**100.222**	**99.674**
O=F	0.463	0.424	0.488	0.489
O=Cl	0.000	0.000	0.000	0.000
Total	**99.646**	**99.754**	**99.734**	**99.185**
apfu				
Si	5.890	5.880	5.909	5.956
Ti	0.000	0.000	0.000	0.001
B	3.000	3.000	3.000	3.000
Al	7.783	7.773	7.749	7.594
Fe^{2+}	0.017	0.042	0.022	0.168
Mn	0.051	0.060	0.055	0.065
Ca	0.071	0.076	0.012	0.016
Zn	0.001	0.001	0.000	0.001
Li	1.254	1.240	1.264	1.214
Na	0.551	0.560	0.668	0.670
K	0.004	0.002	0.009	0.004
H	3.455	3.501	3.427	3.418
F	0.545	0.498	0.573	0.582

Sample	CT.1-3	CT.2-1	CT.2-2	CT.2-3	CT.8-3	CT.10-3	CT.11-1	CT.11-2
SiO_2	37.556	37.633	37.619	37.622	37.558	37.655	37.563	37.444
TiO_2	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000
B_2O_3 calc.	11.068	11.092	11.095	10.617	11.091	11.070	11.051	11.013
Al_2O_3	41.981	42.091	42.077	35.774	42.122	42.001	41.978	41.761
FeO	0.378	0.410	0.444	5.445	0.152	0.202	0.211	0.278
MnO	0.599	0.634	0.616	0.554	0.333	0.222	0.282	0.341
CaO	0.083	0.077	0.083	0.042	0.098	0.026	0.027	0.065
ZnO	0.000	0.000	0.009	0.012	0.012	0.000	0.000	0.000
Li_2O calc.	1.904	1.889	1.898	1.936	2.010	2.003	1.975	1.962
Na_2O	2.002	1.967	2.014	2.245	2.256	2.184	2.118	2.092
K_2O	0.034	0.033	0.041	0.022	0.022	0.032	0.041	0.027
H_2O calc.	3.292	3.318	3.312	3.099	3.247	3.356	3.356	3.306
F	1.111	1.073	1.088	1.191	1.223	0.981	0.967	1.044
Subtotal	**100.008**	**100.217**	**100.296**	**98.568**	**100.124**	**99.732**	**99.569**	**99.332**
O=F	0.468	0.452	0.458	0.501	0.515	0.413	0.407	0.440
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**99.540**	**99.765**	**99.837**	**98.067**	**99.609**	**99.318**	**99.161**	**98.893**
apfu								
Si	5.897	5.896	5.892	6.158	5.885	5.910	5.906	5.907
Ti	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
B	3.000	3.000	3.000	3.000	3.000	2.999	2.999	2.999
Al	7.769	7.773	7.768	6.902	7.780	7.770	7.779	7.766
Fe^{2+}	0.050	0.054	0.058	0.745	0.020	0.027	0.028	0.037
Mn	0.080	0.084	0.082	0.077	0.044	0.030	0.038	0.046
Ca	0.014	0.013	0.014	0.007	0.016	0.004	0.005	0.011
Zn	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000
Li	1.202	1.190	1.195	1.275	1.267	1.264	1.249	1.245
Na	0.609	0.598	0.612	0.713	0.685	0.665	0.646	0.640
K	0.007	0.007	0.008	0.005	0.004	0.006	0.008	0.005
H	3.448	3.468	3.461	3.384	3.394	3.513	3.519	3.479
F	0.552	0.532	0.539	0.617	0.606	0.487	0.481	0.521

Sample	CT.12-1	CT.13-3	CT.13-4	G5-1	G5-2	G5-3	G8.8-1	G8.8-2
SiO_2	37.443	37.558	37.672	36.894	36.844	36.830	36.699	36.722
TiO_2	0.009	0.006	0.000	0.018	0.011	0.009	0.000	0.000
B_2O_3 calc.	10.852	10.997	11.200	10.811	10.789	10.754	10.824	10.826
Al_2O_3	38.233	41.556	42.277	39.410	39.277	39.009	39.922	39.896
FeO	6.134	0.283	0.191	2.800	2.698	2.982	3.198	3.200
MnO	0.564	0.553	0.344	1.215	1.109	0.981	1.115	1.090
CaO	0.066	0.065	0.454	0.113	0.109	0.111	0.122	0.098
ZnO	0.000	0.008	0.012	0.022	0.028	0.014	0.021	0.018
Li_2O calc.	1.377	1.908	2.168	1.629	1.677	1.654	1.497	1.508
Na_2O	2.111	1.891	1.712	2.199	2.310	2.221	1.891	1.933
K_2O	0.009	0.013	0.032	0.018	0.017	0.020	0.011	0.021
H_2O calc.	3.301	3.215	3.348	3.119	3.120	3.177	3.122	3.159
F	0.934	1.223	1.091	1.290	1.272	1.123	1.292	1.215
Subtotal	**101.042**	**99.276**	**100.501**	**99.559**	**99.280**	**98.895**	**99.714**	**99.686**
O=F	0.393	0.515	0.459	0.543	0.536	0.473	0.544	0.512
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**100.648**	**98.761**	**100.041**	**99.016**	**98.745**	**98.422**	**99.170**	**99.174**
apfu								
Si	5.996	5.935	5.844	5.929	5.934	5.952	5.892	5.895
Ti	0.001	0.001	0.000	0.002	0.001	0.001	0.000	0.000
B	3.000	3.000	2.999	2.999	3.000	3.000	3.000	3.000
Al	7.216	7.740	7.731	7.466	7.456	7.431	7.555	7.549
Fe^{2+}	0.821	0.037	0.025	0.376	0.363	0.403	0.429	0.430
Mn	0.076	0.074	0.045	0.165	0.151	0.134	0.152	0.148
Ca	0.011	0.011	0.075	0.019	0.019	0.019	0.021	0.017
Zn	0.000	0.001	0.001	0.003	0.003	0.002	0.002	0.002
Li	0.887	1.212	1.353	1.053	1.086	1.075	0.967	0.974
Na	0.655	0.579	0.515	0.685	0.721	0.696	0.589	0.602
K	0.002	0.003	0.006	0.004	0.003	0.004	0.002	0.004
H	3.526	3.389	3.465	3.344	3.352	3.425	3.344	3.383
F	0.473	0.611	0.535	0.656	0.648	0.574	0.656	0.617

Sample	G8.8-3	G8.9-1	G8.9-2	G8.12-1	G8.12-2
SiO_2	36.788	36.734	36.800	37.599	37.688
TiO_2	0.000	0.000	0.000	0.000	0.000
B_2O_3 calc.	10.835	10.841	10.840	11.030	11.054
Al_2O_3	39.780	39.783	39.710	41.001	41.910
FeO	3.383	3.411	3.392	1.189	0.033
MnO	0.981	1.009	1.133	0.824	0.673
CaO	0.122	0.144	0.161	0.411	0.070
ZnO	0.023	0.019	0.013	0.009	0.000
Li_2O calc.	1.529	1.541	1.525	1.878	1.926
Na_2O	2.004	2.101	2.008	1.923	1.910
K_2O	0.018	0.015	0.021	0.028	0.010
H_2O calc.	3.272	3.223	3.218	3.258	3.298
F	0.983	1.091	1.101	1.154	1.091
Subtotal	**99.718**	**99.920**	**99.921**	**100.313**	**99.663**
O=F	0.414	0.459	0.464	0.486	0.459
O=Cl	0.000	0.000	0.000	0.000	0.000
Total	**99.304**	**99.460**	**99.457**	**99.827**	**99.204**
apfu					
Si	5.901	5.889	5.900	5.924	5.924
Ti	0.000	0.000	0.000	0.000	0.000
B	3.000	3.000	3.000	3.000	2.999
Al	7.521	7.517	7.504	7.614	7.765
Fe^{2+}	0.454	0.457	0.455	0.157	0.004
Mn	0.133	0.137	0.154	0.110	0.090
Ca	0.021	0.025	0.028	0.069	0.012
Zn	0.003	0.002	0.002	0.001	0.000
Li	0.987	0.994	0.983	1.190	1.218
Na	0.623	0.653	0.624	0.587	0.582
K	0.004	0.003	0.004	0.006	0.002
H	3.501	3.447	3.441	3.425	3.458
F	0.499	0.553	0.558	0.575	0.542

Sample	CT.3-1	CT.3-2	CT.3-3	U9V-slab-A-1	U9V-slab-A-2	U9V-slab-A-3	U9V-slab-A-4	U9V-slab-A-5
SiO_2	37.562	37.623	37.600	37.458	37.520	37.570	37.444	37.335
TiO_2	0.008	0.008	0.000	0.012	0.008	0.000	0.012	0.009
B_2O_3 calc.	10.620	10.619	11.088	10.850	10.855	10.862	10.852	10.874
Al_2O_3	35.823	35.773	41.720	38.209	38.318	38.218	37.984	38.113
FeO	5.512	5.499	0.734	6.118	5.988	6.088	6.312	6.166
MnO	0.562	0.533	0.540	0.612	0.585	0.578	0.544	0.484
CaO	0.039	0.036	0.082	0.048	0.055	0.064	0.099	0.566
ZnO	0.018	0.015	0.009	0.000	0.009	0.000	0.000	0.000
Li_2O calc.	1.910	1.933	1.947	1.373	1.380	1.401	1.422	1.496
Na_2O	2.311	2.265	2.334	2.092	1.991	2.034	2.320	2.113
K_2O	0.034	0.028	0.009	0.033	0.017	0.032	0.011	0.009
H_2O calc.	3.080	3.103	3.295	3.208	3.228	3.230	3.202	3.275
F	1.233	1.184	1.119	1.130	1.093	1.094	1.145	1.005
Subtotal	**98.712**	**98.620**	**100.476**	**101.143**	**101.047**	**101.171**	**101.347**	**101.446**
O=F	0.519	0.499	0.471	0.476	0.460	0.461	0.482	0.423
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**98.193**	**98.121**	**100.005**	**100.667**	**100.587**	**100.710**	**100.864**	**101.022**
apfu								
Si	6.147	6.157	5.893	5.999	6.005	6.010	5.995	5.967
Ti	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001
B	3.000	3.000	3.000	3.000	2.999	2.999	2.999	3.000
Al	6.910	6.900	7.708	7.213	7.229	7.206	7.168	7.179
Fe^{2+}	0.754	0.753	0.096	0.819	0.802	0.814	0.845	0.824
Mn	0.078	0.074	0.072	0.083	0.079	0.078	0.074	0.066
Ca	0.007	0.006	0.014	0.008	0.009	0.011	0.017	0.097
Zn	0.002	0.002	0.001	0.000	0.001	0.000	0.000	0.000
Li	1.257	1.272	1.227	0.884	0.888	0.901	0.916	0.962
Na	0.733	0.719	0.709	0.650	0.618	0.631	0.720	0.655
K	0.007	0.006	0.002	0.007	0.003	0.007	0.002	0.002
H	3.362	3.388	3.445	3.427	3.447	3.446	3.420	3.492
F	0.638	0.613	0.555	0.572	0.553	0.553	0.580	0.508

Sample	U9V-slab-B-1	U9V-slab-B-2	U9V-slab-B-3	U9V-slab-B-4	U9V-slab-B-5	U9V-slab-B-6	U9V-slab-B-7	U9V-slab-B-8
SiO_2	37.540	37.406	37.519	37.443	37.482	37.441	37.511	35.980
TiO_2	0.015	0.012	0.009	0.021	0.008	0.013	0.015	0.292
B_2O_3 calc.	10.906	10.914	10.919	10.929	10.920	10.923	10.916	10.214
Al_2O_3	38.093	38.200	38.008	38.454	38.650	38.320	38.155	31.282
FeO	6.256	6.012	6.259	5.785	5.588	5.966	6.100	13.388
MnO	0.510	0.499	0.643	0.454	0.510	0.512	0.478	1.091
CaO	0.534	0.670	0.643	0.595	0.493	0.670	0.873	0.016
ZnO	0.022	0.015	0.008	0.000	0.000	0.022	0.013	0.011
Li_2O calc.	1.486	1.558	1.517	1.566	1.515	1.544	1.541	0.900
Na_2O	2.091	2.215	2.184	2.200	2.009	2.140	1.891	2.334
K_2O	0.022	0.024	0.030	0.025	0.018	0.008	0.013	0.011
H_2O calc.	3.297	3.304	3.291	3.228	3.303	3.231	3.203	3.101
F	0.982	0.973	1.005	1.144	0.981	1.134	1.188	0.893
Subtotal	**101.763**	**101.813**	**102.046**	**101.852**	**101.477**	**101.924**	**101.897**	**99.557**
O=F	0.413	0.410	0.423	0.482	0.413	0.477	0.500	0.376
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**101.349**	**101.403**	**101.623**	**101.370**	**101.064**	**101.446**	**101.397**	**99.181**
apfu								
Si	5.982	5.956	5.972	5.954	5.965	5.957	5.972	6.122
Ti	0.002	0.001	0.001	0.003	0.001	0.002	0.002	0.037
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.155	7.170	7.131	7.207	7.250	7.186	7.160	6.273
Fe^{2+}	0.834	0.801	0.833	0.769	0.744	0.794	0.812	1.905
Mn	0.069	0.067	0.087	0.061	0.069	0.069	0.064	0.157
Ca	0.091	0.114	0.110	0.101	0.084	0.114	0.149	0.003
Zn	0.003	0.002	0.001	0.000	0.000	0.003	0.002	0.001
Li	0.952	0.998	0.971	1.001	0.970	0.988	0.987	0.616
Na	0.646	0.684	0.674	0.678	0.620	0.660	0.584	0.770
K	0.004	0.005	0.006	0.005	0.004	0.002	0.003	0.002
H	3.505	3.510	3.494	3.424	3.506	3.429	3.402	3.520
F	0.495	0.490	0.506	0.575	0.494	0.571	0.598	0.481

Sample	CT.4-1	CT.4-2	CT.4-3	CT.5-1	CT.5-2	CT.5-3	CT.6-1	CT.6-2
SiO_2	37.623	37.619	37.552	37.599	37.640	37.556	37.534	37.444
TiO_2	0.000	0.012	0.000	0.000	0.009	0.000	0.000	0.000
B_2O_3 calc.	11.073	10.601	11.053	11.041	10.779	11.046	11.051	10.946
Al_2O_3	41.571	35.487	41.672	41.566	37.334	41.998	41.856	40.894
FeO	0.674	5.344	0.566	0.612	5.444	0.256	0.270	1.045
MnO	0.650	0.674	0.544	0.484	0.633	0.393	0.356	0.512
CaO	0.064	0.093	0.056	0.062	0.088	0.036	0.041	0.021
ZnO	0.000	0.008	0.000	0.000	0.022	0.009	0.015	0.023
Li_2O calc.	1.946	1.993	1.935	1.942	1.663	1.928	1.979	1.866
Na_2O	2.320	2.337	2.211	2.184	2.114	2.005	2.215	2.084
K_2O	0.034	0.027	0.019	0.022	0.017	0.009	0.013	0.009
H_2O calc.	3.241	3.093	3.296	3.316	3.209	3.286	3.220	3.216
F	1.223	1.193	1.091	1.044	1.073	1.111	1.251	1.184
Subtotal	**100.419**	**98.490**	**99.996**	**99.872**	**100.026**	**99.633**	**99.800**	**99.243**
O=F	0.515	0.502	0.459	0.440	0.452	0.468	0.527	0.499
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**99.904**	**97.988**	**99.536**	**99.432**	**99.574**	**99.165**	**99.273**	**98.745**
apfu								
Si	5.905	6.167	5.904	5.916	6.070	5.907	5.903	5.945
Ti	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000
B	3.000	3.000	3.000	2.999	3.001	2.999	3.000	3.000
Al	7.690	6.857	7.723	7.709	7.097	7.786	7.759	7.653
Fe^{2+}	0.088	0.733	0.074	0.081	0.734	0.034	0.036	0.139
Mn	0.086	0.094	0.072	0.065	0.086	0.052	0.047	0.069
Ca	0.011	0.016	0.009	0.010	0.015	0.006	0.007	0.004
Zn	0.000	0.001	0.000	0.000	0.003	0.001	0.002	0.003
Li	1.228	1.314	1.224	1.229	1.079	1.220	1.252	1.191
Na	0.706	0.743	0.674	0.666	0.661	0.611	0.675	0.642
K	0.007	0.006	0.004	0.004	0.003	0.002	0.003	0.002
H	3.393	3.382	3.457	3.480	3.453	3.447	3.378	3.405
F	0.607	0.619	0.543	0.520	0.547	0.553	0.622	0.595

Sample	CT.6-3	CT.7-2	CT.7-3	CT.9-1	CT.9-2	CT.9-3
SiO_2	37.523	37.562	37.634	37.457	37.523	37.500
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000
B_2O_3 calc.	11.039	10.993	11.080	11.088	11.030	11.054
Al_2O_3	42.011	41.134	42.012	42.123	41.562	41.981
FeO	0.215	0.893	0.192	0.145	0.562	0.343
MnO	0.346	0.512	0.343	0.412	0.494	0.667
CaO	0.045	0.062	0.083	0.114	0.063	0.040
ZnO	0.000	0.012	0.000	0.009	0.009	0.000
Li_2O calc.	1.934	1.901	1.992	2.014	1.936	1.879
Na_2O	1.983	2.111	2.156	2.334	2.161	1.981
K_2O	0.023	0.020	0.023	0.028	0.036	0.020
H_2O calc.	3.344	3.317	3.305	3.225	3.213	3.235
F	0.983	1.005	1.091	1.267	1.251	1.221
Subtotal	**99.446**	**99.531**	**99.912**	**100.216**	**99.840**	**99.920**
O=F	0.414	0.423	0.459	0.533	0.527	0.514
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000
Total	**99.033**	**99.107**	**99.452**	**99.682**	**99.313**	**99.406**
apfu						
Si	5.906	5.937	5.903	5.871	5.912	5.896
Ti	0.000	0.000	0.000	0.000	0.000	0.000
B	2.999	3.000	3.000	3.000	3.000	3.000
Al	7.794	7.664	7.767	7.782	7.718	7.780
Fe^{2+}	0.028	0.118	0.025	0.019	0.074	0.045
Mn	0.046	0.069	0.046	0.055	0.066	0.089
Ca	0.008	0.011	0.014	0.019	0.011	0.007
Zn	0.000	0.001	0.000	0.001	0.001	0.000
Li	1.225	1.209	1.257	1.269	1.227	1.188
Na	0.605	0.647	0.656	0.709	0.660	0.604
K	0.005	0.004	0.005	0.006	0.007	0.004
H	3.511	3.498	3.459	3.372	3.376	3.393
F	0.489	0.502	0.541	0.628	0.623	0.607

Sample	CT.10-1	CT.10-2	CT.13-1	CT.13-2
SiO_2	37.612	37.557	37.623	36.599
TiO_2	0.000	0.022	0.000	0.008
B_2O_3 calc.	11.086	10.875	11.059	10.857
Al_2O_3	41.977	38.730	42.005	41.656
FeO	0.444	4.784	0.019	0.267
MnO	0.645	0.432	0.593	0.563
CaO	0.051	0.032	0.082	0.066
ZnO	0.000	0.022	0.000	0.009
Li_2O calc.	1.904	1.557	1.946	1.821
Na_2O	2.100	2.183	1.983	1.871
K_2O	0.008	0.000	0.018	0.015
H_2O calc.	3.348	3.267	3.306	3.194
F	1.005	1.022	1.077	1.167
Subtotal	**100.180**	**100.483**	**99.711**	**98.094**
O=F	0.423	0.430	0.453	0.491
O=Cl	0.000	0.000	0.000	0.000
Total	**99.757**	**100.053**	**99.258**	**97.602**
apfu				
Si	5.896	6.003	5.910	5.856
Ti	0.000	0.003	0.000	0.001
B	3.000	3.000	2.999	2.999
Al	7.757	7.296	7.778	7.857
Fe^{2+}	0.058	0.639	0.002	0.036
Mn	0.086	0.058	0.079	0.076
Ca	0.009	0.005	0.014	0.011
Zn	0.000	0.003	0.000	0.001
Li	1.201	1.001	1.229	1.172
Na	0.638	0.677	0.604	0.580
K	0.002	0.000	0.004	0.003
H	3.501	3.483	3.465	3.409
F	0.498	0.517	0.535	0.591

Sample	G6-1	G6-2	G6-3	G8.1-1	G8.1-2	G8.1-3	G8.2-1	G8.2-2
SiO_2	36.793	36.732	36.630	36.738	36.770	36.730	36.775	36.700
TiO_2	0.014	0.014	0.245	0.000	0.006	0.011	0.012	0.013
B_2O_3 calc.	10.749	10.728	10.771	10.753	10.756	10.735	10.731	10.711
Al_2O_3	39.022	38.877	36.812	38.730	38.755	38.654	38.599	38.563
FeO	2.893	3.003	9.855	3.788	3.900	3.673	3.599	3.609
MnO	0.891	0.955	0.681	1.134	1.090	1.111	1.081	1.044
CaO	0.107	0.125	0.067	0.199	0.156	0.171	0.171	0.145
ZnO	0.012	0.017	0.000	0.018	0.011	0.009	0.000	0.008
Li_2O calc.	1.680	1.656	0.956	1.564	1.542	1.572	1.591	1.578
Na_2O	2.272	2.236	2.310	2.224	2.191	2.200	2.191	2.174
K_2O	0.024	0.018	0.014	0.009	0.011	0.025	0.031	0.027
H_2O calc.	3.132	3.088	3.198	3.245	3.232	3.162	3.154	3.152
F	1.214	1.293	1.091	0.982	1.012	1.144	1.156	1.145
Subtotal	**98.824**	**98.758**	**102.675**	**99.384**	**99.432**	**99.210**	**99.100**	**98.883**
O=F	0.511	0.544	0.459	0.413	0.426	0.482	0.487	0.482
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**98.313**	**98.214**	**102.215**	**98.970**	**99.006**	**98.728**	**98.613**	**98.400**
apfu								
Si	5.949	5.951	5.910	5.937	5.940	5.946	5.956	5.955
Ti	0.002	0.002	0.030	0.000	0.001	0.001	0.001	0.002
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.437	7.424	7.001	7.377	7.380	7.375	7.368	7.376
Fe^{2+}	0.391	0.407	1.330	0.512	0.527	0.497	0.487	0.490
Mn	0.122	0.131	0.093	0.155	0.149	0.152	0.148	0.143
Ca	0.019	0.022	0.012	0.034	0.027	0.030	0.030	0.025
Zn	0.001	0.002	0.000	0.002	0.001	0.001	0.000	0.001
Li	1.093	1.079	0.620	1.016	1.002	1.023	1.036	1.030
Na	0.712	0.702	0.723	0.697	0.686	0.691	0.688	0.684
K	0.005	0.004	0.003	0.002	0.002	0.005	0.006	0.006
H	3.379	3.337	3.443	3.498	3.483	3.414	3.407	3.412
F	0.621	0.663	0.557	0.502	0.517	0.586	0.592	0.588

Sample	G8.2-3	G8.3-1	G8.3-2	G8.3-3	G8.4-1	G8.4-2	G8.4-3	G8.5-1
SiO_2	36.672	36.588	36.634	36.800	36.793	36.734	36.667	36.800
TiO_2	0.000	0.008	0.000	0.008	0.006	0.000	0.000	0.000
B_2O_3 calc.	10.806	10.804	10.819	10.722	10.725	10.708	10.951	10.963
Al_2O_3	39.334	39.412	39.466	38.560	38.612	38.533	41.554	41.499
FeO	3.445	3.490	3.437	3.550	3.478	3.451	1.288	1.277
MnO	1.166	1.211	1.177	1.087	1.133	1.091	0.676	0.644
CaO	0.122	0.141	0.139	0.155	0.134	0.141	0.167	0.178
ZnO	0.021	0.022	0.015	0.012	0.014	0.009	0.022	0.031
Li_2O calc.	1.574	1.547	1.574	1.583	1.580	1.599	1.785	1.802
Na_2O	2.332	2.278	2.341	2.144	2.155	2.200	2.209	2.181
K_2O	0.009	0.008	0.022	0.013	0.014	0.023	0.008	0.023
H_2O calc.	3.148	3.164	3.156	3.183	3.158	3.105	3.247	3.265
F	1.223	1.189	1.216	1.088	1.144	1.243	1.119	1.091
Subtotal	**99.852**	**99.861**	**99.996**	**98.913**	**98.956**	**98.848**	**99.694**	**99.753**
O=F	0.515	0.501	0.512	0.458	0.482	0.523	0.471	0.459
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**99.337**	**99.360**	**99.484**	**98.455**	**98.474**	**98.324**	**99.222**	**99.294**
apfu								
Si	5.898	5.886	5.885	5.965	5.963	5.962	5.819	5.834
Ti	0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.000
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.457	7.473	7.472	7.368	7.376	7.372	7.773	7.754
Fe^{2+}	0.463	0.470	0.462	0.481	0.471	0.468	0.171	0.169
Mn	0.159	0.165	0.160	0.149	0.156	0.150	0.091	0.086
Ca	0.021	0.024	0.024	0.027	0.023	0.025	0.028	0.030
Zn	0.002	0.003	0.002	0.001	0.002	0.001	0.003	0.004
Li	1.018	1.001	1.017	1.032	1.030	1.044	1.139	1.149
Na	0.727	0.711	0.729	0.674	0.677	0.692	0.680	0.670
K	0.002	0.002	0.005	0.003	0.003	0.005	0.002	0.005
H	3.378	3.395	3.382	3.442	3.413	3.362	3.438	3.452
F	0.622	0.605	0.618	0.558	0.586	0.638	0.562	0.547

Sample	G8.5-2	G8.5-3	L1-2	L1-3	L3-1	L3-2	L3-3	P2-1
SiO_2	36.733	36.776	36.871	36.693	36.555	36.730	36.550	36.783
TiO_2	0.000	0.000	0.009	0.000	0.009	0.009	0.007	0.008
B_2O_3 calc.	10.944	10.831	10.768	10.728	10.708	10.747	10.716	10.778
Al_2O_3	41.453	39.899	38.922	38.870	38.788	38.877	38.566	39.220
FeO	1.265	3.223	3.121	3.221	3.300	3.215	3.822	2.723
MnO	0.559	1.099	1.083	0.983	1.023	1.100	1.091	1.121
CaO	0.175	0.099	0.202	0.234	0.231	0.228	0.223	0.134
ZnO	0.019	0.011	0.011	0.009	0.012	0.008	0.022	0.008
Li_2O calc.	1.811	1.500	1.650	1.625	1.617	1.634	1.577	1.682
Na_2O	2.200	1.901	2.200	2.111	2.172	2.200	2.300	2.331
K_2O	0.012	0.000	0.020	0.018	0.014	0.013	0.019	0.011
H_2O calc.	3.237	3.157	3.189	3.230	3.271	3.281	3.168	3.198
F	1.135	1.223	1.109	0.993	0.893	0.900	1.117	1.100
Subtotal	**99.549**	**99.719**	**99.166**	**98.724**	**98.593**	**98.942**	**99.185**	**99.110**
O=F	0.478	0.515	0.467	0.418	0.376	0.379	0.470	0.463
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**99.071**	**99.204**	**98.699**	**98.306**	**98.217**	**98.563**	**98.714**	**98.647**
apfu								
Si	5.833	5.901	5.951	5.944	5.933	5.940	5.927	5.930
Ti	0.000	0.000	0.001	0.000	0.001	0.001	0.001	0.001
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.759	7.546	7.404	7.422	7.420	7.410	7.371	7.453
Fe^{2+}	0.168	0.432	0.421	0.436	0.448	0.435	0.518	0.367
Mn	0.075	0.149	0.148	0.135	0.141	0.151	0.150	0.153
Ca	0.030	0.017	0.035	0.041	0.040	0.040	0.039	0.023
Zn	0.002	0.001	0.001	0.001	0.001	0.001	0.003	0.001
Li	1.157	0.968	1.071	1.059	1.055	1.063	1.028	1.091
Na	0.677	0.591	0.688	0.663	0.684	0.690	0.723	0.729
K	0.002	0.000	0.004	0.004	0.003	0.003	0.004	0.002
H	3.429	3.379	3.433	3.491	3.542	3.540	3.427	3.439
F	0.570	0.621	0.566	0.509	0.458	0.460	0.573	0.561

Sample	P2-2	P2-3
SiO_2	36.777	36.688
TiO_2	0.013	0.011
B_2O_3 calc.	10.743	10.735
Al_2O_3	38.877	39.009
FeO	2.782	2.922
MnO	1.223	1.091
CaO	0.143	0.213
ZnO	0.008	0.013
Li_2O calc.	1.666	1.638
Na_2O	2.271	2.119
K_2O	0.023	0.009
H_2O calc.	3.195	3.233
F	1.078	0.991
Subtotal	**98.820**	**98.681**
O=F	0.454	0.417
O=Cl	0.000	0.000
Total	**98.366**	**98.264**
apfu		
Si	5.950	5.940
Ti	0.002	0.001
B	3.000	3.000
Al	7.414	7.444
Fe^{2+}	0.376	0.396
Mn	0.168	0.150
Ca	0.025	0.037
Zn	0.001	0.002
Li	1.084	1.066
Na	0.712	0.665
K	0.005	0.002
H	3.448	3.492
F	0.552	0.507

Sample	G8.10-1	G8.10-2	G8.10-3	G8.11-1	G8.11-2	G8.11-3	P1-1	P1-2	P1-3
SiO_2	37.777	37.679	37.722	37.634	37.669	37.653	36.860	36.886	36.830
TiO_2	0.033	0.035	0.034	0.024	0.022	0.009	0.276	0.244	0.011
B_2O_3 calc.	10.956	10.943	10.935	10.927	10.925	11.024	10.802	10.784	10.790
Al_2O_3	39.551	39.512	39.452	39.612	39.583	40.984	36.786	36.555	39.341
FeO	2.566	2.611	2.522	2.466	2.481	1.122	9.799	9.855	2.711
MnO	1.092	1.044	1.101	0.981	1.054	0.822	0.677	0.710	1.010
CaO	0.084	0.094	0.086	0.101	0.104	0.383	0.076	0.072	0.121
ZnO	0.009	0.008	0.008	0.000	0.007	0.000	0.000	0.008	0.009
Li_2O calc.	1.741	1.749	1.751	1.747	1.723	1.881	0.983	0.988	1.690
Na_2O	2.255	2.310	2.282	2.191	2.119	1.891	2.282	2.331	2.300
K_2O	0.018	0.022	0.025	0.031	0.025	0.034	0.021	0.018	0.017
H_2O calc.	3.200	3.209	3.181	3.202	3.214	3.220	3.304	3.259	3.206
F	1.223	1.195	1.251	1.199	1.173	1.233	0.892	0.972	1.091
Subtotal	**100.551**	**100.462**	**100.396**	**100.152**	**100.139**	**100.265**	**102.799**	**102.733**	**99.128**
O=F	0.515	0.503	0.527	0.505	0.494	0.519	0.376	0.409	0.459
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**100.036**	**99.959**	**99.869**	**99.647**	**99.645**	**99.746**	**102.423**	**102.323**	**98.668**
apfu									
Si	5.992	5.983	5.993	5.985	5.992	5.934	5.930	5.944	5.931
Ti	0.004	0.004	0.004	0.003	0.003	0.001	0.033	0.030	0.001
B	3.000	3.000	2.999	3.000	3.000	2.999	3.000	3.000	3.000
Al	7.394	7.396	7.388	7.426	7.421	7.613	6.976	6.944	7.468
Fe^{2+}	0.340	0.347	0.335	0.328	0.330	0.148	1.318	1.328	0.365
Mn	0.147	0.140	0.148	0.132	0.142	0.110	0.092	0.097	0.138
Ca	0.014	0.016	0.015	0.017	0.018	0.065	0.013	0.012	0.021
Zn	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.001
Li	1.111	1.117	1.119	1.118	1.102	1.192	0.636	0.641	1.095
Na	0.694	0.711	0.703	0.676	0.654	0.578	0.712	0.728	0.718
K	0.004	0.004	0.005	0.006	0.005	0.007	0.004	0.004	0.003
H	3.386	3.399	3.371	3.397	3.410	3.385	3.545	3.504	3.444
F	0.614	0.600	0.629	0.603	0.590	0.615	0.454	0.495	0.556

Sample	1-1B-1	1-1B-2	1-1B-3	1.2-1	1.2-2	1.2-3	1.3-1	1.3-2
SiO_2	35.895	35.887	35.875	35.785	35.800	35.854	35.788	35.788
TiO_2	0.189	0.193	0.231	0.226	0.217	0.244	0.231	0.238
B_2O_3 calc.	10.167	10.163	10.173	10.159	10.162	10.218	10.214	10.200
Al_2O_3	31.262	31.244	31.500	31.484	31.555	31.890	32.011	31.877
FeO	13.181	13.174	13.091	13.086	13.100	12.891	12.871	12.855
MnO	1.012	1.034	1.033	1.100	1.007	1.100	1.081	1.004
CaO	0.031	0.027	0.045	0.055	0.052	0.041	0.044	0.051
ZnO	0.000	0.008	0.000	0.000	0.008	0.010	0.012	0.007
Li_2O calc.	0.924	0.921	0.879	0.853	0.850	0.832	0.803	0.841
Na_2O	2.191	2.177	2.009	2.014	1.967	2.112	2.092	2.130
K_2O	0.027	0.025	0.009	0.013	0.017	0.033	0.023	0.000
H_2O calc.	2.979	2.982	3.088	3.053	3.047	2.979	2.971	2.965
F	1.116	1.108	0.891	0.955	0.970	1.154	1.168	1.170
Subtotal	**99.026**	**98.987**	**98.845**	**98.806**	**98.782**	**99.413**	**99.360**	**99.187**
O=F	0.470	0.467	0.375	0.402	0.408	0.486	0.492	0.493
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**98.556**	**98.521**	**98.470**	**98.404**	**98.374**	**98.927**	**98.869**	**98.694**
apfu								
Si	6.135	6.136	6.129	6.122	6.122	6.098	6.089	6.097
Ti	0.024	0.025	0.030	0.029	0.028	0.031	0.030	0.030
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	6.298	6.297	6.343	6.348	6.361	6.393	6.420	6.401
Fe^{2+}	1.884	1.884	1.870	1.872	1.874	1.834	1.832	1.832
Mn	0.147	0.150	0.149	0.159	0.146	0.158	0.156	0.145
Ca	0.006	0.005	0.008	0.010	0.010	0.007	0.008	0.009
Zn	0.000	0.001	0.000	0.000	0.001	0.001	0.002	0.001
Li	0.635	0.634	0.604	0.587	0.584	0.569	0.549	0.576
Na	0.726	0.722	0.665	0.668	0.652	0.697	0.690	0.704
K	0.006	0.005	0.002	0.003	0.004	0.007	0.005	0.000
H	3.397	3.401	3.519	3.484	3.476	3.379	3.372	3.370
F	0.603	0.599	0.481	0.517	0.525	0.621	0.629	0.630

Sample	1.3-3	1.4-1	1.4-2	1.4-3	1.5-1	1.5-2	1.5-3	1.6-1
SiO_2	35.888	35.799	36.003	35.875	35.985	36.220	35.895	36.044
TiO_2	0.022	0.237	0.209	0.288	0.300	0.287	0.300	0.282
B_2O_3 calc.	10.206	10.219	10.245	10.205	10.226	10.266	10.189	10.209
Al_2O_3	32.098	32.100	32.078	31.566	31.600	31.540	31.333	31.292
FeO	12.677	12.800	12.766	13.222	13.272	13.251	13.523	13.494
MnO	0.893	0.883	0.789	0.940	0.874	0.904	0.873	0.834
CaO	0.044	0.037	0.042	0.050	0.051	0.046	0.065	0.067
ZnO	0.000	0.000	0.000	0.021	0.011	0.008	0.000	0.000
Li_2O calc.	0.892	0.843	0.918	0.874	0.892	0.964	0.866	0.919
Na_2O	2.111	2.151	2.134	2.200	2.183	2.256	2.121	2.134
K_2O	0.022	0.014	0.044	0.021	0.009	0.014	0.000	0.012
H_2O calc.	3.004	2.986	2.985	2.938	2.944	3.030	2.947	2.968
F	1.093	1.140	1.161	1.231	1.233	1.081	1.200	1.170
Subtotal	**98.995**	**99.253**	**99.411**	**99.462**	**99.619**	**99.898**	**99.368**	**99.488**
O=F	0.460	0.480	0.489	0.518	0.519	0.455	0.505	0.493
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**98.535**	**98.773**	**98.922**	**98.944**	**99.100**	**99.443**	**98.863**	**98.995**
apfu								
Si	6.111	6.088	6.107	6.109	6.115	6.132	6.122	6.136
Ti	0.003	0.030	0.027	0.037	0.038	0.037	0.038	0.036
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	6.442	6.435	6.414	6.336	6.330	6.294	6.299	6.279
Fe^{2+}	1.805	1.821	1.811	1.883	1.886	1.876	1.929	1.921
Mn	0.129	0.127	0.113	0.136	0.126	0.130	0.126	0.120
Ca	0.008	0.007	0.008	0.009	0.009	0.008	0.012	0.012
Zn	0.000	0.000	0.000	0.003	0.001	0.001	0.000	0.000
Li	0.611	0.577	0.626	0.599	0.610	0.656	0.594	0.629
Na	0.697	0.709	0.702	0.726	0.719	0.741	0.701	0.704
K	0.005	0.003	0.010	0.005	0.002	0.003	0.000	0.003
H	3.412	3.387	3.377	3.337	3.338	3.422	3.353	3.370
F	0.589	0.613	0.623	0.663	0.663	0.579	0.647	0.630

Sample	1.6-2	1.6-3	1.7-2	1.7-3	U2-1	U2-2	U2-3	U2A-1
SiO_2	36.210	35.984	35.922	36.233	36.734	36.789	36.784	36.659
TiO_2	0.277	0.254	0.301	0.202	0.271	0.282	0.211	0.209
B_2O_3 calc.	10.235	10.191	10.193	10.269	10.823	10.838	10.832	10.832
Al_2O_3	31.317	31.562	31.566	31.891	37.055	37.100	37.400	37.502
FeO	13.477	13.075	13.101	12.873	9.884	9.900	9.562	9.655
MnO	0.780	0.935	0.873	0.677	0.682	0.692	0.723	0.812
CaO	0.070	0.036	0.041	0.026	0.071	0.074	0.089	0.088
ZnO	0.000	0.007	0.000	0.007	0.000	0.013	0.021	0.023
Li_2O calc.	0.965	0.899	0.899	1.005	0.961	0.961	0.941	0.898
Na_2O	2.111	1.934	2.032	2.225	2.345	2.331	2.112	2.092
K_2O	0.013	0.032	0.030	0.008	0.009	0.012	0.022	0.027
H_2O calc.	3.000	2.971	2.941	3.077	3.277	3.279	3.204	3.204
F	1.122	1.151	1.216	0.985	0.963	0.970	1.124	1.123
Subtotal	**99.629**	**99.062**	**99.147**	**99.520**	**103.116**	**103.267**	**103.044**	**103.155**
O=F	0.472	0.485	0.512	0.415	0.405	0.408	0.473	0.473
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**99.156**	**98.577**	**98.635**	**99.105**	**102.710**	**102.859**	**102.571**	**102.682**
apfu								
Si	6.148	6.136	6.125	6.132	5.898	5.899	5.901	5.882
Ti	0.035	0.033	0.039	0.026	0.033	0.034	0.025	0.025
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	6.268	6.344	6.344	6.361	7.013	7.012	7.072	7.092
Fe^{2+}	1.914	1.865	1.868	1.822	1.327	1.328	1.283	1.295
Mn	0.112	0.135	0.126	0.097	0.093	0.094	0.098	0.110
Ca	0.013	0.007	0.007	0.005	0.012	0.013	0.015	0.015
Zn	0.000	0.001	0.000	0.001	0.000	0.002	0.002	0.003
Li	0.659	0.617	0.616	0.684	0.620	0.620	0.607	0.579
Na	0.695	0.639	0.672	0.730	0.730	0.725	0.657	0.651
K	0.003	0.007	0.007	0.002	0.002	0.002	0.005	0.006
H	3.398	3.380	3.345	3.473	3.510	3.507	3.429	3.429
F	0.603	0.621	0.656	0.527	0.489	0.492	0.570	0.570

Sample	U2A-2	U2A-3	U3-1	U3-2	U3-3	U4-1	U4-2	U4-3
SiO_2	36.700	36.800	36.693	36.773	36.800	36.745	36.755	36.672
TiO_2	0.226	0.202	0.234	0.262	0.236	0.209	0.241	0.236
B_2O_3 calc.	10.843	10.828	10.817	10.844	10.873	10.853	10.854	10.826
Al_2O_3	37.448	37.344	37.402	37.337	37.734	37.642	37.662	37.412
FeO	9.587	9.634	9.630	9.663	9.101	9.092	9.005	9.255
MnO	0.782	0.686	0.644	0.722	0.845	0.794	0.785	0.682
CaO	0.092	0.087	0.072	0.084	0.091	0.101	0.113	0.087
ZnO	0.021	0.007	0.011	0.007	0.000	0.000	0.013	0.008
Li_2O calc.	0.947	0.941	0.929	0.953	0.987	1.008	1.014	1.009
Na_2O	2.232	2.114	2.092	2.222	2.194	2.254	2.200	2.312
K_2O	0.026	0.019	0.024	0.016	0.033	0.023	0.040	0.022
H_2O calc.	3.223	3.270	3.309	3.288	3.234	3.216	3.226	3.207
F	1.091	0.982	0.892	0.955	1.091	1.113	1.094	1.114
Subtotal	**103.246**	**102.935**	**102.771**	**103.159**	**103.259**	**103.078**	**103.028**	**102.897**
O=F	0.459	0.413	0.376	0.402	0.459	0.469	0.461	0.469
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**102.786**	**102.522**	**102.396**	**102.757**	**102.800**	**102.609**	**102.567**	**102.428**
apfu								
Si	5.882	5.906	5.895	5.893	5.882	5.884	5.885	5.887
Ti	0.027	0.024	0.028	0.032	0.028	0.025	0.029	0.028
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.074	7.065	7.083	7.053	7.109	7.104	7.108	7.079
Fe^{2+}	1.285	1.293	1.294	1.295	1.217	1.218	1.206	1.242
Mn	0.106	0.093	0.088	0.098	0.114	0.108	0.106	0.093
Ca	0.016	0.015	0.012	0.014	0.016	0.017	0.019	0.015
Zn	0.002	0.001	0.001	0.001	0.000	0.000	0.002	0.001
Li	0.611	0.607	0.600	0.614	0.634	0.649	0.653	0.651
Na	0.694	0.658	0.652	0.690	0.680	0.700	0.683	0.720
K	0.005	0.004	0.005	0.003	0.007	0.005	0.008	0.005
H	3.446	3.501	3.546	3.515	3.448	3.435	3.445	3.434
F	0.553	0.498	0.453	0.484	0.551	0.564	0.554	0.566

Sample	U6-1	U6-2	U6-3	U9-1	U9-2	U9-3	U9A-1	U9A-2
SiO_2	36.800	36.703	36.773	36.693	36.592	36.800	36.763	36.730
TiO_2	0.251	0.262	0.244	0.256	0.252	0.272	0.288	0.267
B_2O_3 calc.	10.847	10.837	10.800	10.794	10.804	10.844	10.826	10.831
Al_2O_3	37.399	37.400	37.004	36.983	37.120	37.223	37.191	37.200
FeO	9.312	9.225	9.923	9.836	9.841	9.712	9.692	9.772
MnO	0.702	0.683	0.673	0.733	0.709	0.812	0.811	0.771
CaO	0.090	0.082	0.072	0.066	0.072	0.088	0.093	0.093
ZnO	0.032	0.017	0.000	0.000	0.009	0.010	0.013	0.011
Li_2O calc.	1.005	1.030	0.913	0.930	0.942	0.944	0.924	0.937
Na_2O	2.282	2.380	2.119	2.214	2.320	2.229	2.130	2.233
K_2O	0.019	0.016	0.012	0.019	0.013	0.022	0.017	0.018
H_2O calc.	3.225	3.243	3.247	3.191	3.206	3.322	3.339	3.313
F	1.091	1.045	1.009	1.123	1.100	0.883	0.834	0.893
Subtotal	**103.101**	**102.968**	**102.837**	**102.889**	**103.017**	**103.206**	**102.972**	**103.118**
O=F	0.459	0.440	0.425	0.473	0.463	0.372	0.351	0.376
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**102.642**	**102.528**	**102.413**	**102.416**	**102.554**	**102.834**	**102.621**	**102.742**
apfu								
Si	5.896	5.886	5.917	5.907	5.886	5.898	5.901	5.893
Ti	0.030	0.032	0.030	0.031	0.030	0.033	0.035	0.032
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.063	7.070	7.019	7.018	7.038	7.032	7.037	7.035
Fe^{2+}	1.248	1.237	1.335	1.324	1.324	1.302	1.301	1.311
Mn	0.095	0.093	0.092	0.100	0.097	0.110	0.110	0.105
Ca	0.015	0.014	0.012	0.011	0.012	0.015	0.016	0.016
Zn	0.004	0.002	0.000	0.000	0.001	0.001	0.002	0.001
Li	0.648	0.664	0.591	0.602	0.610	0.609	0.597	0.605
Na	0.709	0.740	0.661	0.691	0.724	0.693	0.663	0.695
K	0.004	0.003	0.002	0.004	0.003	0.004	0.003	0.004
H	3.446	3.469	3.486	3.427	3.440	3.552	3.576	3.546
F	0.553	0.530	0.514	0.572	0.560	0.448	0.423	0.453

Sample	U9A-3	U9-2	U9-3	U10B-1	U10B-2	U10B-3	10C-1	10C-2
SiO_2	36.630	36.788	36.930	36.783	36.674	36.594	36.720	36.670
TiO_2	0.233	0.260	0.016	0.272	0.288	0.266	0.312	0.282
B_2O_3 calc.	10.778	10.383	10.812	10.791	10.817	10.803	10.833	10.816
Al_2O_3	36.893	32.165	39.412	36.857	37.002	36.783	36.812	36.773
FeO	9.903	12.445	2.783	9.847	9.888	10.383	10.412	10.373
MnO	0.720	0.756	1.113	0.782	0.823	0.890	0.923	0.930
CaO	0.082	0.059	0.101	0.092	0.083	0.093	0.113	0.104
ZnO	0.000	0.011	0.021	0.009	0.000	0.008	0.014	0.009
Li_2O calc.	0.924	1.127	1.649	0.912	0.935	0.881	0.881	0.885
Na_2O	2.222	2.122	2.224	2.092	2.316	2.345	2.312	2.334
K_2O	0.023	0.024	0.009	0.025	0.024	0.034	0.028	0.030
H_2O calc.	3.201	3.208	3.142	3.201	3.215	3.262	3.252	3.210
F	1.091	0.790	1.244	1.101	1.090	0.981	1.023	1.100
Subtotal	**102.763**	**100.194**	**99.470**	**102.835**	**103.218**	**103.371**	**103.685**	**103.561**
O=F	0.459	0.333	0.524	0.464	0.459	0.413	0.431	0.463
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**102.304**	**99.862**	**98.946**	**102.371**	**102.759**	**102.958**	**103.254**	**103.097**
apfu								
Si	5.907	6.157	5.935	5.924	5.892	5.887	5.891	5.892
Ti	0.028	0.033	0.002	0.033	0.035	0.032	0.038	0.034
B	3.000	3.000	2.999	3.000	3.000	3.000	3.000	3.000
Al	7.012	6.346	7.465	6.997	7.007	6.974	6.961	6.964
Fe^{2+}	1.335	1.742	0.374	1.326	1.329	1.397	1.397	1.394
Mn	0.098	0.107	0.152	0.107	0.112	0.121	0.125	0.127
Ca	0.014	0.011	0.017	0.016	0.014	0.016	0.019	0.018
Zn	0.000	0.001	0.002	0.001	0.000	0.001	0.002	0.001
Li	0.599	0.759	1.066	0.591	0.604	0.570	0.569	0.572
Na	0.695	0.689	0.693	0.653	0.721	0.731	0.719	0.727
K	0.005	0.005	0.002	0.005	0.005	0.007	0.006	0.006
H	3.443	3.582	3.368	3.439	3.445	3.500	3.480	3.440
F	0.556	0.418	0.632	0.561	0.554	0.499	0.519	0.559

Sample	10C-3	U13-1	U13-2	U13-3	U14-1	U14-2	U14-3	U15-1
SiO_2	36.673	36.595	36.700	36.494	36.677	36.800	36.770	36.683
TiO_2	0.222	0.289	0.231	0.244	0.272	0.187	0.231	0.247
B_2O_3 calc.	10.806	10.747	10.795	10.741	10.775	10.899	10.775	10.773
Al_2O_3	36.860	36.550	36.784	36.556	36.520	37.765	36.530	36.510
FeO	10.191	10.588	10.201	10.556	10.523	10.104	10.567	10.600
MnO	0.861	0.653	0.903	0.700	0.672	0.700	0.585	0.624
CaO	0.089	0.056	0.093	0.067	0.071	0.104	0.083	0.077
ZnO	0.012	0.000	0.021	0.000	0.000	0.033	0.000	0.000
Li_2O calc.	0.905	0.837	0.882	0.853	0.898	0.865	0.889	0.887
Na_2O	2.320	2.092	2.223	2.223	2.310	2.101	2.211	2.294
K_2O	0.028	0.027	0.018	0.022	0.029	0.031	0.022	0.019
H_2O calc.	3.149	3.285	3.139	3.335	3.333	3.190	3.252	3.199
F	1.220	0.892	1.234	0.781	0.810	1.201	0.981	1.091
Subtotal	**103.367**	**102.653**	**103.261**	**102.613**	**102.934**	**104.001**	**102.941**	**103.064**
O=F	0.514	0.376	0.520	0.329	0.341	0.506	0.413	0.459
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**102.853**	**102.277**	**102.741**	**102.284**	**102.593**	**103.495**	**102.528**	**102.604**
apfu								
Si	5.898	5.918	5.908	5.905	5.915	5.868	5.930	5.918
Ti	0.027	0.035	0.028	0.030	0.033	0.022	0.028	0.030
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	6.987	6.967	6.980	6.972	6.943	7.098	6.945	6.942
Fe^{2+}	1.371	1.432	1.373	1.428	1.419	1.347	1.425	1.430
Mn	0.117	0.089	0.123	0.096	0.092	0.095	0.080	0.085
Ca	0.015	0.010	0.016	0.012	0.012	0.018	0.014	0.013
Zn	0.001	0.000	0.002	0.000	0.000	0.004	0.000	0.000
Li	0.585	0.544	0.571	0.555	0.582	0.554	0.577	0.575
Na	0.723	0.656	0.694	0.697	0.722	0.650	0.691	0.718
K	0.006	0.006	0.004	0.005	0.006	0.006	0.005	0.004
H	3.379	3.543	3.371	3.600	3.586	3.393	3.499	3.443
F	0.621	0.456	0.628	0.400	0.413	0.606	0.500	0.557

Sample	U15-2	U15-3	U17-1	U17-2	U17-3	U18B-1	U18B-2	U18B-3
SiO_2	36.675	36.672	36.682	36.644	36.662	35.893	35.994	36.011
TiO_2	0.258	0.238	0.209	0.213	0.278	0.277	0.301	0.211
B_2O_3 calc.	10.778	10.352	10.345	10.353	10.805	10.191	10.242	10.184
Al_2O_3	36.633	32.145	31.944	32.005	37.023	31.199	31.620	31.233
FeO	10.562	12.510	12.712	12.777	9.834	13.422	13.218	13.092
MnO	0.655	0.744	0.668	0.712	0.720	1.113	1.081	0.983
CaO	0.082	0.054	0.041	0.037	0.064	0.022	0.026	0.022
ZnO	0.008	0.018	0.012	0.011	0.000	0.013	0.008	0.009
Li_2O calc.	0.865	1.087	1.117	1.089	0.950	0.884	0.875	0.975
Na_2O	2.198	2.022	2.156	2.223	2.315	2.314	2.277	2.221
K_2O	0.022	0.028	0.034	0.026	0.014	0.028	0.021	0.020
H_2O calc.	3.187	3.159	3.052	3.035	3.267	3.090	3.068	2.977
F	1.120	0.872	1.091	1.134	0.972	0.900	0.983	1.132
Subtotal	**103.097**	**99.949**	**100.114**	**100.302**	**102.950**	**99.394**	**99.751**	**99.115**
O=F	0.472	0.367	0.459	0.477	0.409	0.379	0.414	0.477
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**102.626**	**99.581**	**99.654**	**99.825**	**102.541**	**99.015**	**99.337**	**98.638**
apfu								
Si	5.913	6.157	6.162	6.151	5.896	6.121	6.108	6.145
Ti	0.031	0.030	0.026	0.027	0.034	0.036	0.038	0.027
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	6.962	6.361	6.325	6.332	7.019	6.271	6.324	6.282
Fe^{2+}	1.424	1.756	1.786	1.794	1.323	1.914	1.876	1.869
Mn	0.089	0.106	0.095	0.101	0.098	0.161	0.155	0.142
Ca	0.014	0.010	0.007	0.007	0.011	0.004	0.005	0.004
Zn	0.001	0.002	0.001	0.001	0.000	0.002	0.001	0.001
Li	0.561	0.734	0.755	0.735	0.614	0.606	0.597	0.669
Na	0.687	0.658	0.702	0.724	0.722	0.765	0.749	0.735
K	0.005	0.006	0.007	0.006	0.003	0.006	0.005	0.004
H	3.428	3.537	3.421	3.398	3.505	3.515	3.473	3.389
F	0.571	0.463	0.580	0.602	0.494	0.485	0.528	0.611

Sample	CZ2-1	CZ2-2	CZ2-3	CZ3A-1	CZ3A-2	CZ3A-3	CZ4-1	CZ4-2
SiO_2	36.579	36.662	36.700	36.512	36.533	36.680	36.492	36.783
TiO_2	0.156	0.173	0.213	0.245	0.241	0.260	0.235	0.231
B_2O_3 calc.	10.802	10.824	10.361	10.774	10.773	10.771	10.756	10.822
Al_2O_3	37.720	37.685	32.092	37.310	37.271	36.933	37.123	37.173
FeO	8.663	8.683	12.672	9.523	9.555	9.745	9.693	9.775
MnO	0.889	0.904	0.709	0.484	0.620	0.720	0.682	0.640
CaO	0.093	0.110	0.034	0.078	0.074	0.044	0.045	0.038
ZnO	0.021	0.009	0.009	0.008	0.000	0.008	0.014	0.021
Li_2O calc.	0.994	1.019	1.094	0.943	0.920	0.915	0.894	0.942
Na_2O	2.114	2.189	2.133	2.100	2.053	2.110	2.078	2.233
K_2O	0.009	0.015	0.041	0.032	0.042	0.022	0.025	0.021
H_2O calc.	3.264	3.229	3.097	3.190	3.202	3.273	3.225	3.212
F	0.976	1.064	1.009	1.111	1.085	0.934	1.023	1.100
Subtotal	**102.305**	**102.597**	**100.214**	**102.388**	**102.433**	**102.473**	**102.345**	**103.042**
O=F	0.411	0.448	0.425	0.468	0.457	0.393	0.431	0.463
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**101.894**	**102.149**	**99.789**	**101.920**	**101.976**	**102.079**	**101.915**	**102.579**
apfu								
Si	5.885	5.887	6.156	5.889	5.893	5.918	5.896	5.907
Ti	0.019	0.021	0.027	0.030	0.029	0.032	0.029	0.028
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.153	7.132	6.345	7.094	7.087	7.024	7.070	7.037
Fe^{2+}	1.166	1.166	1.778	1.285	1.289	1.315	1.310	1.313
Mn	0.121	0.123	0.101	0.066	0.085	0.098	0.093	0.087
Ca	0.016	0.019	0.006	0.013	0.013	0.008	0.008	0.007
Zn	0.002	0.001	0.001	0.001	0.000	0.001	0.002	0.002
Li	0.643	0.658	0.738	0.612	0.597	0.594	0.581	0.609
Na	0.659	0.681	0.694	0.657	0.642	0.660	0.651	0.695
K	0.002	0.003	0.009	0.007	0.009	0.005	0.005	0.004
H	3.503	3.459	3.465	3.432	3.446	3.523	3.477	3.441
F	0.497	0.540	0.535	0.567	0.554	0.477	0.523	0.559

Sample	CZ4-3	CZ5-1	CZ5-2	CZ5-3	CZ6-1	CZ6-2	CZ6-3	CZ7-1
SiO_2	36.730	36.652	36.734	36.696	36.840	36.730	36.555	36.723
TiO_2	0.199	0.189	0.184	0.188	0.137	0.141	0.155	0.123
B_2O_3 calc.	10.811	10.809	10.813	10.808	10.858	10.830	10.825	10.847
Al_2O_3	37.455	37.500	37.482	37.677	37.782	37.700	37.834	37.773
FeO	9.212	9.225	9.194	8.840	8.950	8.870	8.778	8.900
MnO	0.699	0.734	0.733	0.785	0.783	0.800	0.892	0.883
CaO	0.056	0.062	0.056	0.060	0.059	0.072	0.090	0.098
ZnO	0.009	0.011	0.008	0.007	0.000	0.013	0.000	0.000
Li_2O calc.	0.975	0.967	0.968	0.976	1.004	1.006	0.998	1.004
Na_2O	2.123	2.145	2.110	2.023	2.193	2.177	2.200	2.213
K_2O	0.033	0.037	0.027	0.009	0.014	0.026	0.033	0.037
H_2O calc.	3.156	3.211	3.188	3.150	3.179	3.185	3.217	3.264
F	1.210	1.091	1.144	1.220	1.195	1.162	1.091	1.007
Subtotal	**102.691**	**102.654**	**102.664**	**102.450**	**103.008**	**102.725**	**102.682**	**102.887**
O=F	0.509	0.459	0.482	0.514	0.503	0.489	0.459	0.424
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**102.182**	**102.195**	**102.182**	**101.936**	**102.505**	**102.236**	**102.222**	**102.463**
apfu								
Si	5.904	5.893	5.904	5.901	5.897	5.894	5.869	5.884
Ti	0.024	0.023	0.022	0.023	0.016	0.017	0.019	0.015
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.097	7.107	7.101	7.141	7.128	7.131	7.159	7.133
Fe^{2+}	1.238	1.240	1.236	1.189	1.198	1.190	1.179	1.193
Mn	0.095	0.100	0.100	0.107	0.106	0.109	0.121	0.120
Ca	0.010	0.011	0.010	0.010	0.010	0.012	0.015	0.017
Zn	0.001	0.001	0.001	0.001	0.000	0.002	0.000	0.000
Li	0.630	0.625	0.626	0.631	0.646	0.649	0.644	0.647
Na	0.662	0.669	0.658	0.631	0.681	0.677	0.685	0.687
K	0.007	0.008	0.006	0.002	0.003	0.005	0.007	0.008
H	3.384	3.444	3.418	3.379	3.394	3.409	3.445	3.489
F	0.615	0.555	0.582	0.620	0.605	0.590	0.554	0.510

Sample	CZ7-2	CZ7-3	OP1-1	OP1-2	OP1-3	G1-1	G1-2	G1-3
SiO_2	36.811	36.675	36.800	36.777	36.672	36.512	36.494	36.555
TiO_2	0.142	0.133	0.147	0.154	0.181	0.196	0.205	0.211
B_2O_3 calc.	10.870	10.817	10.850	10.859	10.824	10.326	10.323	10.312
Al_2O_3	37.749	37.556	37.562	37.664	37.788	31.912	31.845	31.800
FeO	8.874	8.934	8.944	8.874	8.674	12.799	12.873	12.777
MnO	0.910	0.845	0.955	0.972	0.894	0.707	0.729	0.673
CaO	0.094	0.101	0.105	0.097	0.083	0.031	0.022	0.043
ZnO	0.022	0.000	0.000	0.009	0.008	0.015	0.014	0.009
Li_2O calc.	1.028	1.007	1.018	1.018	0.993	1.082	1.075	1.108
Na_2O	2.310	2.231	2.295	2.311	2.092	2.310	2.347	2.191
K_2O	0.027	0.012	0.018	0.022	0.009	0.015	0.022	0.018
H_2O calc.	3.228	3.265	3.277	3.209	3.268	3.099	3.109	3.058
F	1.100	0.983	0.983	1.133	0.983	0.978	0.956	1.056
Subtotal	**103.183**	**102.591**	**102.980**	**103.141**	**102.491**	**100.020**	**100.055**	**99.847**
O=F	0.463	0.414	0.414	0.477	0.414	0.412	0.403	0.445
O=Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**102.720**	**102.177**	**102.566**	**102.664**	**102.077**	**99.608**	**99.652**	**99.402**
apfu								
Si	5.886	5.893	5.895	5.886	5.888	6.145	6.144	6.160
Ti	0.017	0.016	0.018	0.019	0.022	0.025	0.026	0.027
B	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Al	7.114	7.112	7.092	7.105	7.151	6.331	6.319	6.317
Fe^{2+}	1.187	1.200	1.198	1.188	1.165	1.802	1.812	1.801
Mn	0.123	0.115	0.130	0.132	0.122	0.101	0.104	0.096
Ca	0.016	0.017	0.018	0.017	0.014	0.006	0.004	0.008
Zn	0.003	0.000	0.000	0.001	0.001	0.002	0.002	0.001
Li	0.661	0.651	0.656	0.655	0.641	0.732	0.728	0.751
Na	0.716	0.695	0.713	0.717	0.651	0.754	0.766	0.716
K	0.006	0.002	0.004	0.004	0.002	0.003	0.005	0.004
H	3.443	3.500	3.501	3.426	3.500	3.480	3.491	3.438
F	0.556	0.499	0.498	0.573	0.499	0.521	0.509	0.563

Sample	G2-1	G2-2	G2-3
SiO_2	35.494	36.612	36.634
TiO_2	0.216	0.236	0.233
B_2O_3 calc.	10.136	10.336	10.778
Al_2O_3	31.871	31.901	37.213
FeO	12.845	12.882	9.444
MnO	0.663	0.600	0.550
CaO	0.048	0.039	0.088
ZnO	0.008	0.014	0.009
Li_2O calc.	0.848	1.100	0.959
Na_2O	2.155	2.200	2.091
K_2O	0.033	0.017	0.022
H_2O calc.	2.976	3.048	3.252
F	1.100	1.093	0.983
Subtotal	**98.425**	**100.106**	**102.323**
O=F	0.463	0.460	0.414
O=Cl	0.000	0.000	0.000
Total	**97.962**	**99.646**	**101.909**
apfu			
Si	6.086	6.156	5.907
Ti	0.028	0.030	0.028
B	3.000	3.000	3.000
Al	6.441	6.322	7.073
Fe^{2+}	1.842	1.811	1.274
Mn	0.096	0.085	0.075
Ca	0.009	0.007	0.015
Zn	0.001	0.002	0.001
Li	0.585	0.744	0.622
Na	0.716	0.717	0.654
K	0.007	0.004	0.005
H	3.404	3.419	3.498
F	0.596	0.581	0.501

Microprobe analyses for all Feldspar

Standards for EMP analyses for **mica and feldspar** Acceleration potential: 15 Kv Beam current: 15 nA Beam width: 2 microns Count times: 45 seconds per spot	
Albite, Tiburen	Si, Al, Na
Adularia, Fibbia	K, Si
An_{50}, Nain, Canada	Ca, Al
Clinopyroxene, "Cpx-26"	Fe, Mg
$BaSO_4$, Synthetic	(Ba)
$SrSO_4$, Synthetic	(Sr)
Fluorapatite, Cerro de Mercado Mexico	F,P
$KMg_3AlSi_3O_{10}F_2$, synthetic	F
Pollucite, Tanco	Cs
Rhodonite, Broken Hill	Mn
$RbAlSi_2O_6$, synthetic	Rb
TiO_2, synthetic	Ti
Other MAN standards used: Al_2O_3, synthetic Hematite, Elba MgO, synthetic PbO, synthetic V_2O_5, synthetic ZnO, synthetic ZrO_2, synthetic	

All feldspar analyses were calculated based on 8 oxygen.

Plagioclase

Plagioclase	CZ-1-1	CZ-1-2	CZ-1-3	CZ-2-1	CZ-2-2	CZ-2-3	CZ-3A-1	CZ-3A-2
oxide								
SiO_2	68.774	68.966	70.008	68.611	68.588	68.6	68.766	68.733
TiO_2	0	0	0	0	0	0	0	0
Al_2O_3	19.512	19.607	19.453	19.512	19.465	19.432	19.523	19.6
FeO	0	0	0	0	0	0	0	0
CaO	0.355	0.383	0.282	0.033	0.043	0.054	0.009	0.012
MnO	0	0	0	0	0	0	0	0
K_2O	0.023	0.033	0.027	0.121	0.105	0.091	0.045	0.112
Na_2O	11.56	11.544	11.877	11.655	11.595	11.611	11.667	11.557
P_2O_5	0	0	0.008	0	0	0	0	0
SrO	0	0	0	0	0	0	0	0
Rb_2O	0	0	0	0	0	0	0	0
Cs_2O	0	0	0	0	0	0	0	0
Total	100.224	100.533	101.655	99.932	99.796	99.788	100.01	100.014
apfu								
Si	2.996	2.995	3.007	2.997	2.999	3.000	2.999	2.998
Ti	0	0	0	0	0	0	0	0
Al	1.002	1.004	0.985	1.005	1.003	1.002	1.004	1.008
Fe	0	0	0	0	0	0	0	0
Ca	0.017	0.019	0.013	0.002	0.002	0.003	0.000	0.001
Mn	0	0	0	0	0	0	0	0
K	0.001	0.002	0.001	0.007	0.006	0.005	0.003	0.006
Na	0.976	0.972	0.989	0.987	0.983	0.984	0.987	0.977
P	0	0	0.001	0	0	0	0	0
Sr	0	0	0	0	0	0	0	0
Rb	0	0	0	0	0	0	0	0
Cs	0	0	0	0	0	0	0	0
An	1.667	1.797	1.293	0.155	0.203	0.255	0.043	0.057
Ab	98.205	98.0181	98.559	99.1672	99.205	99.2333	99.705	99.31
Or	0.129	0.184	0.147	0.6778	0.591	0.511	0.253	0.6332

Plagioclase	CZ-3A-3	CZ3-B-1	CZ3-B-2	CZ3-B-3	CZ4-1	CZ4-2	CZ4-3	CZ4-4
oxide								
SiO_2	68.761	68.65	68.282	68.022	67.488	67.455	67.311	67.607
TiO_2	0.009	0	0	0	0	0	0	0
Al_2O_3	19.477	19.987	19.81	19.798	20.001	20.012	20.087	20.1
FeO	0	0	0	0	0	0	0	0.004
CaO	0.022	0.564	0.62	0.634	1.78	1.844	2.111	0.544
MnO	0	0	0	0.008	0	0	0	0
K_2O	0.085	0.171	0.233	0.181	0.077	0.122	0.212	0.034
Na_2O	11.611	10.778	10.671	10.71	9.95	9.87	9.78	11.122
P_2O_5	0.008	0.009	0	0.009	0.011	0	0.009	0.009
SrO	0	0.009	0	0.008	0.021	0.009	0.013	0
Rb_2O	0	0	0	0	0	0	0	0
Cs_2O	0	0	0	0	0	0	0	0
Total	99.973	100.168	99.616	99.37	99.328	99.312	99.523	99.42
apfu								
Si	3.001	2.988	2.989	2.986	2.967	2.967	2.958	2.969
Ti	0.000	0	0	0	0	0	0	0
Al	1.002	1.025	1.025	1.024	1.036273	1.037	1.040357	1.040
Fe	0	0	0	0	0	0	0	0.000147
Ca	0.001	0.026	0.029	0.03	0.084	0.087	0.099	0.026
Mn	0	0	0	0.000	0	0	0	0
K	0.005	0.01	0.013	0.010	0.004	0.007	0.012	0.002
Na	0.982	0.909	0.906	0.911	0.848	0.841	0.833	0.947
P	0.000	0.000	0	0.000	0.001	0	0.000	0.000
Sr	0	0.000	0	0.000	0.001	0.000	0.	0
Rb	0	0	0	0	0	0	0	0
Cs	0	0	0	0	0	0	0	0
An	0.104	2.782	3.068	3.134	8.955	9.29	10.523	2.627
Ab	99.417	96.213	95.559	95.801	90.584	89.978	88.219	97.178
Or	0.4789	1.004	1.373	1.065	0.461	0.732	1.258	0.196

Plagioclase	CZ5-1	CZ5-2	CZ5-3	CZ6-1	CZ6-2	CZ6-3	CZ7-1	CZ7-2
oxide								
SiO_2	68.333	68.455	68.51	68.155	68.122	68.177	68.344	68.347
TiO_2	0	0	0	0	0	0	0	0
Al_2O_3	19.4	19.388	19.4	19.651	19.71	19.699	19.566	19.6
FeO	0	0	0	0	0	0	0	0
CaO	0.012	0.011	0.065	0.778	0.745	0.683	0.98	1.19
MnO	0	0	0	0	0	0	0	0
K_2O	0.211	0.188	0.21	0.044	0.084	0.034	0.05	0.031
Na_2O	11.3	11.55	11.422	11.001	10.913	10.933	10.89	10.971
P_2O_5	0	0	0	0	0	0	0	0
SrO	0	0	0	0.008	0	0.006	0.011	0.013
Rb_2O	0	0	0	0	0	0	0	0
Cs_2O	0	0	0	0	0	0	0	0
Total	99.256	99.592	99.607	99.637	99.574	99.532	99.841	100.152
apfu								
Si	3.003	3.001	3.002	2.986	2.986	2.988	2.989	2.983
Ti	0	0	0	0	0	0	0	0
Al	1.005	1.002	1.002	1.015	1.018	1.017	1.009	1.008
Fe	0	0	0	0	0	0	0	0
Ca	0.001	0.001	0.003	0.037	0.035	0.032	0.046	0.056
Mn	0	0	0	0	0	0	0	0
K	0.012	0.011	0.012	0.003	0.005	0.002	0.003	0.002
Na	0.963	0.981	0.970	0.934	0.927	0.929	0.923	0.928
P	0	0	0	0	0	0	0	0
Sr	0	0	0	0.000	0	0.000	0.000	0.000
Rb	0	0	0	0	0	0	0	0
Cs	0	0	0	0	0	0	0	0
An	0.058	0.052	0.31	3.752	3.618	3.331	4.724	5.645
Ab	98.729	98.889	98.497	95.996	95.897	96.472	94.989	94.18
Or	1.213	1.059	1.192	0.253	0.486	0.197	0.287	0.175

Plagioclase	CZ7-3	CZ8-1	CZ8-2	CZ8-3	G1-1	G1-2	G1-3	G2-1
oxide								
SiO_2	68.344	69.101	69.122	69.2	69.243	69.334	69.141	68.388
TiO_2	0	0	0	0	0	0	0	0
Al_2O_3	19.585	19.494	19.477	19.5	19.444	19.4	19.322	19.792
FeO	0	0	0	0	0	0	0	0
CaO	0.891	0	0.008	0.009	0.189	0.231	0.211	0.983
MnO	0	0	0	0	0	0	0	0
K_2O	0.063	0.093	0.067	0.044	0.1	0.099	0.078	0.088
Na_2O	10.891	11.788	11.688	11.655	11.65	11.556	11.589	10.781
P_2O_5	0.009				0	0	0	0.007
SrO	0.01	0	0	0	0	0	0	0.009
Rb_2O	0	0	0	0	0	0	0	0.191
Cs_2O	0	0	0	0	0	0	0	0
Total	99.793	100.476	100.362	100.408	100.626	100.62	100.341	100.239
apfu								
Si	2.990	3.002	3.004	3.005	3.004	3.007	3.007	2.983
Ti	0	0	0	0	0	0	0	0
Al	1.010	0.998	0.998	0.998	0.994	0.992	0.990	1.017
Fe	0	0	0	0	0	0	0	0
Ca	0.042	0	0.000	0.000	0.009	0.011	0.010	0.046
Mn	0	0	0	0	0	0	0	0
K	0.004	0.005	0.004	0.002	0.006	0.006	0.004	0.005
Na	0.924	0.993	0.985	0.981	0.980	0.972	0.977	0.912
P	0.000	0	0	0	0	0	0	0.000
Sr	0.000	0	0	0	0	0	0	0.000
Rb	0	0	0	0	0	0	0	0.005
Cs	0	0	0	0	0	0	0	0
An	4.31	0	0.038	0.043	0.884	1.087	0.992	4.773
Ab	95.327	99.484	99.587	99.710	98.560	98.359	98.572	94.719
Or	0.363	0.516	0.376	0.248	0.557	0.554	0.437	0.509

Plagioclase	G3-1	G3-2	G3-3	L1-1	L1-2	L1-3	L2-1	L2-2
oxide								
SiO_2	68.44	68.51	68.533	68.488	68.712	68.344	68.5	68.709
TiO_2	0.025	0.033	0.019	0	0	0	0	0
Al_2O_3	19.561	19.5	19.595	19.6	19.585	19.512	19.566	19.422
FeO	0	0	0	0	0	0	0.022	0.014
CaO	0.112	0.141	0.148	0	0	0.008	0.089	0.119
MnO	0	0	0	0	0	0	0	0
K_2O	0.1	0.078	0.066	0.088	0.123	0.144	0.212	0.222
Na_2O	11.223	11.2	11.091	11.64	11.558	11.609	11.599	11.7
P_2O_5	0	0.008	0	0.012	0	0	0.009	0.006
SrO	0	0	0	0	0	0	0	0
Rb_2O	0	0	0	0	0	0	0	0
Cs_2O	0	0	0	0	0	0	0	0
Total	99.461	99.47	99.452	99.828	99.978	99.617	99.997	100.192
apfu								
Si	2.999	3.001	3.001	2.994	2.998	2.995	2.993	2.997
Ti	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Al	1.010	1.007	1.011	1.010	1.007	1.008	1.008	0.999
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Ca	0.005	0.007	0.007	0.000	0.000	0.000	0.004	0.006
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.006	0.004	0.004	0.005	0.007	0.008	0.012	0.012
Na	0.953	0.951	0.942	0.987	0.978	0.986	0.983	0.990
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.545	0.688	0.729	0.000	0.000	0.038	0.417	0.552
Ab	98.875	98.859	98.884	99.505	99.305	99.153	98.399	98.222
Or	0.580	0.453	0.387	0.495	0.695	0.809	1.183	1.226

Plagioclase	L2-3	L3-4	L3-5	L3-6	OP1-1	OP1-2	OP1-3	1-1-1
oxide								
SiO_2	68.488	68.655	68.600	68.562	68.700	68.556	68.830	68.700
TiO_2	0.000	0.033	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.544	19.440	19.600	19.455	19.550	19.343	19.600	19.555
FeO	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.123	0.093	0.055	0.098	0.123	0.109	0.133	0.055
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.199	0.343	0.227	0.272	0.224	0.300	0.244	0.223
Na_2O	11.677	11.455	11.600	11.556	11.450	11.123	11.383	11.455
P_2O_5	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000
SrO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	100.046	100.039	100.082	99.943	100.047	99.431	100.190	99.988
apfu								
Si	2.992	2.998	2.994	2.997	2.998	3.007	2.998	2.999
Ti	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.006	1.001	1.008	1.002	1.005	1.000	1.006	1.006
Fe	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.006	0.004	0.003	0.005	0.006	0.005	0.006	0.003
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.011	0.019	0.013	0.015	0.012	0.017	0.014	0.012
Na	0.989	0.970	0.981	0.979	0.969	0.946	0.961	0.969
P	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.572	0.438	0.258	0.459	0.583	0.529	0.633	0.261
Ab	98.325	97.638	98.474	98.023	98.154	97.736	97.985	98.477
Or	1.103	1.924	1.268	1.518	1.263	1.734	1.382	1.261

Plagioclase	1-1-2	1-1-3	1.1B-2	1.1B-3	1.1B-4	1-2-1	1-2-2	1-2-3
oxide								
SiO_2	68.568	68.458	68.650	68.562	68.623	68.555	68.600	68.545
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.431	19.650	19.500	19.444	19.409	19.451	19.388	19.400
FeO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.034	0.028	0.028	0.033	0.028	0.023	0.026	0.030
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.098	0.144	0.120	0.033	0.041	0.230	0.199	0.156
Na_2O	11.600	11.393	11.556	11.501	11.405	11.700	11.655	11.566
P_2O_5	0.000	0.009	0.009	0.009	0.000	0.000	0.000	0.000
SrO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.320	0.299	0.255
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000
Total	99.731	99.682	99.863	99.582	99.506	100.279	100.178	99.952
apfu								
Si	3.000	2.995	2.999	3.002	3.005	2.995	2.999	3.000
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.002	1.013	1.004	1.003	1.002	1.001	0.999	1.001
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.005	0.008	0.007	0.002	0.002	0.013	0.011	0.009
Na	0.984	0.966	0.979	0.976	0.968	0.991	0.988	0.981
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.009	0.008	0.007
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.161	0.135	0.133	0.158	0.135	0.107	0.122	0.142
Ab	99.287	99.042	99.189	99.654	99.629	98.617	98.769	98.980
Or	0.552	0.824	0.678	0.188	0.236	1.276	1.110	0.878

Plagioclase	1.3-1	1.3-2	1.3-3	1.4-1	1.4-2	1.4-3	1.5-1	1.5-2
oxide								
SiO_2	67.840	67.832	67.895	68.444	68.520	68.433	68.888	68.345
TiO_2	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.912	19.788	19.890	19.430	19.431	19.330	19.450	19.650
FeO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	1.661	1.445	1.630	0.000	0.009	0.000	0.760	0.455
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.112	0.210	0.043	0.220	0.150	0.166	0.044	0.064
Na_2O	10.344	10.440	10.441	11.550	11.494	11.650	11.122	11.400
P_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011
SrO	0.013	0.015	0.012	0.000	0.000	0.000	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	99.882	99.730	99.918	99.644	99.604	99.579	100.264	99.925
apfu								
Si	2.970	2.974	2.970	2.999	3.001	3.001	2.999	2.987
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.027	1.023	1.025	1.003	1.003	0.999	0.998	1.012
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.078	0.068	0.076	0.000	0.000	0.000	0.035	0.021
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.006	0.012	0.002	0.012	0.008	0.009	0.002	0.004
Na	0.878	0.887	0.886	0.981	0.976	0.990	0.939	0.966
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	8.098	7.019	7.922	0.000	0.043	0.000	3.630	2.150
Ab	91.252	91.766	91.829	98.762	99.106	99.071	96.120	97.490
Or	0.650	1.215	0.249	1.238	0.851	0.929	0.250	0.360

Plagioclase	1.5-3	1.6-1	1.6-2	1.6-3	1.7-1	1.7-2	1.7-3	U2-pf-1
oxide								
SiO_2	68.789	68.566	68.500	68.623	68.566	68.600	68.544	68.630
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.820	19.700	19.699	19.782	19.444	19.394	19.431	19.433
FeO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.510	0.333	0.423	0.455	0.000	0.009	0.000	0.000
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.100	0.121	0.091	0.089	0.100	0.089	0.088	0.101
Na_2O	11.250	11.010	11.023	11.003	11.700	11.595	11.650	11.600
P_2O_5	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SrO	0.000	0.033	0.012	0.009	0.000	0.000	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	100.478	99.763	99.748	99.961	99.810	99.687	99.713	99.764
apfu								
Si	2.988	2.996	2.994	2.993	2.999	3.002	3.000	3.002
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.015	1.014	1.015	1.017	1.002	1.000	1.002	1.002
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.024	0.016	0.020	0.021	0.000	0.000	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.006	0.007	0.005	0.005	0.006	0.005	0.005	0.006
Na	0.947	0.933	0.934	0.930	0.992	0.984	0.988	0.984
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	2.430	1.632	2.066	2.223	0.000	0.043	0.000	0.000
Ab	97.003	97.661	97.405	97.260	99.441	99.455	99.505	99.430
Or	0.567	0.706	0.529	0.518	0.559	0.502	0.495	0.570

Plagioclase	U2-pf-2	U2-3	U2A-1	U2A-2	U2A-3	U3-1	U3-2	U3-3
oxide								
SiO_2	68.683	68.562	68.600	68.778	68.586	68.555	68.612	68.633
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.383	19.430	19.388	19.410	19.433	19.373	19.388	19.344
FeO	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.089	0.067	0.312	0.282	0.278	0.233	0.214	0.312
Na_2O	11.566	11.494	11.633	11.566	11.589	11.677	11.744	11.686
P_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SrO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	99.721	99.562	99.933	100.036	99.886	99.838	99.958	99.975
apfu								
Si	3.004	3.003	3.000	3.002	2.999	3.000	2.999	3.001
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.999	1.003	0.999	0.999	1.002	0.999	0.999	0.997
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.005	0.004	0.017	0.016	0.016	0.013	0.012	0.017
Na	0.981	0.976	0.986	0.979	0.983	0.991	0.995	0.990
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ab	99.496	99.618	98.266	98.421	98.446	98.704	98.815	98.274
Or	0.504	0.382	1.734	1.579	1.554	1.296	1.185	1.726

Plagioclase	U4-1	U4-2	U4-3	U6-1	U6-2	U6-3	U9-1	U9-2
oxide								
SiO_2	68.673	68.663	68.673	68.556	68.612	68.710	68.722	68.699
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.411	19.355	19.540	19.955	20.133	20.110	19.555	19.574
FeO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.033	0.031	0.025	1.230	1.336	1.432	0.000	0.000
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.122	0.156	0.145	0.100	0.109	0.133	0.122	0.091
Na_2O	11.562	11.445	11.494	10.344	10.450	10.400	11.556	11.543
P_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SrO	0.000	0.000	0.000	0.011	0.008	0.008	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	99.801	99.650	99.877	100.196	100.648	100.793	99.955	99.907
apfu								
Si	3.002	3.005	3.000	2.984	2.976	2.976	2.999	2.999
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.000	0.998	1.006	1.024	1.029	1.027	1.006	1.007
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.002	0.001	0.001	0.057	0.062	0.066	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.007	0.009	0.008	0.006	0.006	0.007	0.007	0.005
Na	0.980	0.971	0.973	0.873	0.879	0.873	0.978	0.977
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.156	0.148	0.119	6.129	6.557	7.016	0.000	0.000
Ab	99.155	98.964	99.059	93.277	92.806	92.208	99.310	99.484
Or	0.688	0.888	0.822	0.593	0.637	0.776	0.690	0.516

Plagioclase	U9-3	U10A-1	U10A-2	U10A-3	U10B-1	U10B-2	U10B-3	U10c-1
oxide								
SiO_2	68.711	68.558	68.612	68.667	68.711	68.558	68.622	68.556
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.600	19.633	19.599	19.600	19.456	19.487	19.511	19.488
FeO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.012	0.000	0.000	0.000	0.000	0.000	0.022	0.000
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.102	0.110	0.088	0.067	0.089	0.099	0.081	0.211
Na_2O	11.548	11.559	11.640	11.449	11.561	11.543	11.561	11.540
P_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SrO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	99.973	99.860	99.939	99.783	99.817	99.687	99.797	99.795
apfu								
Si	2.998	2.995	2.996	3.000	3.002	3.000	3.000	2.999
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.008	1.011	1.009	1.009	1.002	1.005	1.005	1.005
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.006	0.006	0.005	0.004	0.005	0.006	0.005	0.012
Na	0.977	0.979	0.985	0.970	0.979	0.979	0.980	0.979
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.057	0.000	0.000	0.000	0.000	0.000	0.105	0.000
Ab	99.365	99.378	99.505	99.616	99.496	99.439	99.437	98.811
Or	0.577	0.622	0.495	0.384	0.504	0.561	0.458	1.189

Plagioclase	U10c-2	U10c-3	U13-1	U13-2	U13-3	U14-1	U14-2	U14-3
oxide								
SiO_2	68.611	68.556	68.539	68.544	68.477	68.644	68.563	68.655
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.477	19.521	19.448	19.488	19.512	19.488	19.434	19.512
FeO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.000	0.000	0.009	0.000	0.000	0.044	0.034	0.044
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.136	0.132	0.121	0.091	0.114	0.111	0.088	0.078
Na_2O	11.595	11.611	11.650	11.673	11.556	11.334	11.412	11.403
P_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SrO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	99.819	99.820	99.767	99.796	99.659	99.621	99.531	99.692
apfu								
Si	3.000	2.998	2.999	2.998	2.998	3.003	3.003	3.002
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.004	1.006	1.003	1.004	1.007	1.005	1.003	1.006
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.008	0.007	0.007	0.005	0.006	0.006	0.005	0.004
Na	0.983	0.984	0.988	0.990	0.981	0.961	0.969	0.967
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.000	0.000	0.042	0.000	0.000	0.213	0.164	0.212
Ab	99.234	99.258	99.279	99.490	99.355	99.148	99.332	99.341
Or	0.766	0.742	0.678	0.510	0.645	0.639	0.504	0.447

Plagioclase	U15-1	U15-2	U15-3	U16B -1	U16B -2	U16B -3	U17-1	U17-2
oxide								
SiO_2	68.455	68.500	68.512	68.677	68.623	68.477	68.311	68.151
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.566	19.451	19.599	19.445	19.388	19.722	19.773	19.677
FeO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.344	0.367	0.443	0.000	0.000	0.008	0.656	0.568
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.088	0.121	0.099	0.078	0.088	0.070	0.055	0.074
Na_2O	11.223	11.266	11.091	11.555	11.612	11.577	11.211	11.133
P_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SrO	0.000	0.007	0.000	0.000	0.000	0.000	0.008	0.012
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	99.676	99.712	99.744	99.755	99.711	99.854	100.014	99.615
apfu								
Si	2.996	2.998	2.996	3.003	3.003	2.992	2.983	2.987
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.009	1.003	1.010	1.002	1.000	1.016	1.018	1.016
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.016	0.017	0.021	0.000	0.000	0.000	0.031	0.027
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.005	0.007	0.006	0.004	0.005	0.004	0.003	0.004
Na	0.952	0.956	0.940	0.979	0.985	0.981	0.949	0.946
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	1.657	1.756	2.147	0.000	0.000	0.038	3.123	2.731
Ab	97.838	97.554	97.281	99.558	99.504	99.566	96.566	96.846
Or	0.505	0.689	0.571	0.442	0.496	0.396	0.312	0.424

Plagioclase	U17-3	U18A-1	U18A-2	U18A-3	U18B-1	U18B-2	U18B-3
oxide							
SiO_2	68.199	68.400	68.452	68.377	68.433	68.393	68.312
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	19.380	19.393	19.366	19.412	19.440	19.288	19.344
FeO	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.623	0.009	0.000	0.000	0.000	0.009	0.000
MnO	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.088	0.355	0.445	0.345	0.540	0.445	0.440
Na_2O	11.098	11.655	11.588	11.550	11.455	11.623	11.555
P_2O_5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SrO	0.008	0.000	0.000	0.000	0.000	0.000	0.000
Rb_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	99.396	99.812	99.851	99.684	99.868	99.758	99.651
apfu							
Si	2.995	2.996	2.998	2.998	2.997	2.999	2.998
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.003	1.001	1.000	1.003	1.003	0.997	1.000
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.029	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.005	0.020	0.025	0.019	0.030	0.025	0.025
Na	0.945	0.990	0.984	0.982	0.973	0.988	0.983
P	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	2.994	0.042	0.000	0.000	0.000	0.042	0.000
Ab	96.503	97.994	97.536	98.072	96.992	97.502	97.556
Or	0.503	1.964	2.465	1.928	3.008	2.456	2.444

Feldspar

Feldspar	CZ-1-4	CZ-1-5	CZ-1-6	CZ-2-4	CZ-2-5	CZ-2-6	CZ-3A-4	CZ-3A-5
oxide								
SiO_2	64.442	64.312	64.544	64.595	64.562	64.484	64.623	64.595
TiO_2	0.000	0.009	0.011	0.014	0.009	0.013	0.034	0.009
Al_2O_3	18.355	18.655	18.431	18.355	18.354	18.288	18.277	18.300
FeO	0.006	0.000	0.000	0.000	0.008	0.000	0.006	0.000
CaO	0.000	0.009	0.000	0.008	0.000	0.000	0.000	0.000
K_2O	16.344	15.788	16.522	16.393	16.512	16.448	15.985	16.006
Na_2O	0.221	0.198	0.200	0.232	0.181	0.255	0.455	0.430
P_2O_5	0.022	0.017	0.022	0.017	0.009	0.023	0.011	0.014
Rb_2O	0.091	0.155	0.134	0.133	0.122	0.144	0.177	0.153
Cs_2O	0.000	0.010	0.016	0.000	0.012	0.023	0.009	0.016
Total	99.481	99.153	99.880	99.747	99.769	99.678	99.577	99.523
apfu								
Si	2.996	2.992	2.993	2.997	2.997	2.997	3.000	3.000
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Al	1.006	1.023	1.007	1.004	1.004	1.002	1.000	1.002
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.969	0.937	0.977	0.970	0.978	0.975	0.947	0.948
Na	0.020	0.018	0.018	0.021	0.016	0.023	0.041	0.039
P	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.001
Rb	0.003	0.005	0.004	0.004	0.004	0.004	0.005	0.005
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.000	0.047	0.000	0.040	0.000	0.000	0.000	0.000
Ab	2.014	1.869	1.806	2.105	1.639	2.302	4.147	3.923
Or	97.986	98.084	98.194	97.855	98.361	97.698	95.853	96.077

Feldspar	CZ-3A-6	CZ3-B-4	CZ3-B-5	CZ3-B-6	CZ4-5	CZ4-6	CZ6-4	CZ6-5
oxide								
SiO_2	64.445	64.677	64.655	64.599	64.595	64.600	64.534	64.561
TiO_2	0.008	0.009	0.014	0.013	0.007	0.011	0.011	0.000
Al_2O_3	18.232	18.400	18.288	18.300	18.410	18.366	18.262	18.288
FeO	0.000	0.007	0.000	0.000	0.008	0.000	0.021	0.023
CaO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	16.433	16.440	16.511	16.433	16.433	16.334	16.400	16.383
Na_2O	0.282	0.211	0.191	0.211	0.233	0.255	0.322	0.282
P_2O_5	0.022	0.032	0.022	0.034	0.034	0.012	0.009	0.012
Rb_2O	0.120	0.122	0.144	0.170	0.093	0.100	0.145	0.177
Cs_2O	0.000	0.013	0.014	0.022	0.000	0.000	0.000	0.000
Total	99.542	99.911	99.839	99.782	99.813	99.678	99.704	99.726
apfu								
Si	2.998	2.996	2.999	2.998	2.995	2.998	2.998	2.998
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.000	1.004	1.000	1.001	1.006	1.004	1.000	1.001
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.975	0.971	0.977	0.973	0.972	0.967	0.972	0.970
Na	0.025	0.019	0.017	0.019	0.021	0.023	0.029	0.025
P	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000
Rb	0.004	0.004	0.004	0.005	0.003	0.003	0.004	0.005
Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
An	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ab	2.542	1.913	1.728	1.914	2.109	2.318	2.898	2.549
Or	97.458	98.087	98.272	98.086	97.891	97.682	97.102	97.451

Feldspar	CZ6-6	G1-4	G1-5	G1-6	L3-1	L3-2	L3-3	OP1-4
oxide								
SiO_2	64.499	64.556	64.561	64.484	64.433	64.334	64.412	64.55
TiO_2	0.009	0.009	0	0	0.009	0.013	0.009	0.04
Al_2O_3	18.3	18.234	18.133	18.292	18.444	18.544	18.444	18.322
FeO	0.005	0	0	0	0.008	0	0	0.029
CaO	0.009	0	0	0	0.011	0	0.007	0.015
K_2O	16.3	16.555	16.499	16.334	16.365	16.32	16.4	16.711
Na_2O	0.299	0.055	0.045	0.211	0.255	0.434	0.282	0.132
P_2O_5	0.009	0.009	0.011	0.008	0.022	0.013	0.016	0.009
Rb_2O	0.21	0.133	0.122	0.091	0.132	0.122	0.099	0.098
Cs_2O	0	0	0	0	0	0	0	0
Total	99.64	99.551	99.371	99.42	99.679	99.78	99.669	99.906
apfu								
Si	2.997	3.002	3.006	2.999	2.992	2.986	2.992	2.995
Ti	0.000	0.000	0	0	0.000	0.001	0.000	0.001
Al	1.002	0.999	0.995	1.003	1.009	1.014	1.01	1.002
Fe	0.000	0	0	0	0.000	0	0	0.001
Ca	0.001	0	0	0	0.001	0	0.000	0.001
K	0.966	0.982	0.98	0.969	0.969	0.966	0.972	0.989
Na	0.027	0.005	0.004	0.019	0.023	0.039	0.025	0.012
P	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000
Rb	0.006	0.004	0.004	0.003	0.004	0.004	0.003	0.003
Cs	0	0	0	0	0	0	0	0
An	0.045	0	0	0	0.055	0	0.035	0.074
Ab	2.711	0.502	0.413	1.925	2.312	3.885	2.546	1.185
Or	97.244	99.498	99.587	98.075	97.633	96.115	97.419	98.740

Feldspar	OP1-5	OP1-6	1-1-4	1-1-5	1-1-6	1.4-4	1.4-5	1.4-6
oxide								
SiO_2	64.65	64.567	64.643	64.55	64.566	64.466	64.445	64.5
TiO_2	0.009	0.04	0.008	0	0.01	0.009	0	0
Al_2O_3	19.432	18.351	18.4	18.344	18.5	18.4	18.384	18.411
FeO	0.013	0.023	0	0	0	0	0	0
CaO	0.09	0.123	0	0	0	0	0	0
K_2O	16.556	16.556	16.344	16.4	16.332	16.56	16.555	16.393
Na_2O	0.222	0.191	0.43	0.322	0.327	0.233	0.31	0.161
P_2O_5	0.013	0.014	0.012	0.022	0.019	0.009	0.012	0.011
Rb_2O	0.094	0.144	0.111	0.13	0.122	0.121	0.109	0.122
Cs_2O	0	0	0	0	0	0	0	0
Total	101.079	100.009	99.948	99.768	99.876	99.798	99.815	99.598
apfu								
Si	2.962132	2.992581	2.994003	2.99557	2.991534	2.992889	2.992085	2.996169
Ti	0.00031	0.001395	0.000279	0	0.000349	0.000314	0	0
Al	1.049261	1.002363	1.004335	1.003246	1.010164	1.006718	1.0059	1.007892
Fe	0.000498	0.000891	0	0	0	0	0	0
Ca	0.004418	0.006107	0	0	0	0	0	0
K	0.96761	0.978813	0.965602	0.970814	0.965247	0.980684	0.980444	0.971346
Na	0.019719	0.017162	0.038609	0.028969	0.029372	0.020971	0.027902	0.014499
P	0.000504	0.000549	0.000471	0.000864	0.000745	0.000354	0.000472	0.000433
Rb	0.002768	0.00429	0.003304	0.003877	0.003633	0.00361	0.003253	0.003642
Cs	0	0	0	0	0	0	0	0
An	0.445451	0.609479	0	0	0	0	0	0
Ab	1.988303	1.712614	3.844753	2.897528	2.953082	2.093592	2.767138	1.47068
Or	97.56625	97.67791	96.15525	97.10247	97.04692	97.90641	97.23286	98.52932

Feldspar	1.5-4	1.5-5	1.5-6	1.7-4	1.7-5	1.7-6	U2A-4	U2A-5
oxide								
SiO_2	64.32	64.55	64.7	64.65	64.566	64.568	64.455	64.544
TiO_2	0	0	0	0.008	0.02	0	0	0
Al_2O_3	18.42	18.333	18.53	18.334	18.222	18.366	18.4	18.433
FeO	0	0	0	0	0	0	0	0
CaO	0.01	0.009	0.008	0	0	0	0	0
K_2O	16.444	16.62	16.7	16.446	16.522	16.566	16.422	16.355
Na_2O	0.232	0.225	0.34	0.322	0.298	0.302	0.434	0.455
P_2O_5	0.012	0.026	0.017	0.032	0.029	0.018	0	0
Rb_2O	0.155	0.145	0.211	0.233	0.254	0.222	0.312	0.282
Cs_2O	0	0	0	0.011	0.019	0.013	0.021	0.019
Total	99.593	99.908	100.506	100.036	99.93	100.055	100.044	100.088
apfu								
Si	2.992	2.995	2.988	2.995	2.997	2.993	2.990	2.991
Ti	0	0	0	0.000	0.001	0	0	0
Al	1.01	1.002	1.008	1.001	0.997	1.003	1.006	1.007
Fe	0	0	0	0	0	0	0	0
Ca	0.001	0.001	0.000	0	0	0	0	0
K	0.976	0.984	0.984	0.972	0.978	0.98	0.972	0.967
Na	0.021	0.020	0.030	0.029	0.027	0.027	0.0390	0.041
P	0.001	0.001	0.001	0.001	0.001	0.001	0	0
Rb	0.005	0.004	0.006	0.0067	0.008	0.007	0.009	0.008
Cs	0	0	0	0.000	0.000	0.000	0.000	0.000
An	0.05	0.045	0.039	0	0	0	0	0
Ab	2.098	2.015	3.000	2.89	2.668	2.696	3.861	4.057
Or	97.852	97.940	96.961	97.110	97.332	97.304	96.139	95.943

Feldspar	U2A-6	U4-4	U4-5	U4-6	U6-4	U6-5	U6-6	U9-4
oxide								
SiO_2	64.433	64.446	64.5	64.522	64.52	64.439	64.437	64.555
TiO_2	0	0	0.008	0	0	0	0	0.011
Al_2O_3	18.366	18.399	18.355	18.44	18.305	18.433	18.453	18.355
FeO	0	0	0	0	0.009	0.011	0.008	0
CaO	0	0.011	0	0.009	0.011	0.019	0.022	0
K_2O	16.55	16.344	16.316	16.444	16.009	19.1	16.044	16.566
Na_2O	0.512	0.445	0.523	0.445	0.555	0.622	0.555	0.334
P_2O_5	0	0	0.008	0.009	0	0	0	0.011
Rb_2O	0.275	0.255	0.311	0.288	0.232	0.199	0.191	0.133
Cs_2O	0.017	0.025	0.022	0.019	0	0.011	0	0
Total	100.153	99.925	100.043	100.176	99.641	102.834	99.71	99.965
apfu								
Si	2.989	2.991	2.991	2.989	2.997	2.957	2.991	2.993
Ti	0	0	0.000	0	0	0	0	0.000
Al	1.004	1.006	1.003	1.007	1.002	0.997	1.009	1.003
Fe	0	0	0	0	0.000	0.000	0.000	0
Ca	0	0.001	0	0.001	0.001	0.001	0.001	0
K	0.979	0.966	0.965	0.972	0.949	1.118	0.95	0.98
Na	0.0460	0.040	0.047	0.04	0.05	0.055	0.049	0.03
P	0	0	0.000	0.000	0	0	0	0.000
Rb	0.008	0.008	0.009	0.009	0.007	0.006	0.006	0.004
Cs	0.000	0.001	0.000	0.000	0	0.000	0	0
An	0	0.054	0	0.044	0.055	0.08	0.109	0
Ab	4.491	3.971	4.645	3.949	5.002	4.712	4.989	2.973
Or	95.509	95.974	95.355	96.007	94.942	95.208	94.9012	97.027

Feldspar	U9-5	U10A-4	U10A-5	U10A-6	U18A-4	U18A-5	U18A-6
oxide							
SiO_2	65.522	64.558	64.562	64.512	64.447	64.44	64.388
TiO_2	0	0	0	0	0	0.011	0
Al_2O_3	18.341	18.344	18.411	18.399	18.433	18.445	18.6
FeO	0	0	0	0	0	0	0
CaO	0	0	0	0	0	0	0
K_2O	16.674	16.445	16.56	16.585	16.44	16.344	16.51
Na_2O	0.412	0.233	0.255	0.31	0.344	0.256	0.41
P_2O_5	0.007	0.022	0.019	0.021	0.032	0.019	0.018
Rb_2O	0.154	0	0.199	0.189	0.312	0.282	0.266
Cs_2O	0.014	0	0	0	0.022	0.018	0.012
Total	101.124	99.602	100.006	100.016	100.03	99.815	100.204
apfu							
Si	3.003	2.9981	2.993	2.991	2.989	2.992	2.983
Ti	0	0	0	0	0	0.000	0
Al	0.9917	1.004	1.0067	1.005	1.008	1.009	1.015
Fe	0	0	0	0	0	0	0
Ca	0	0	0	0	0	0	0
K	0.975	0.974	0.979	0.981	0.973	0.968	0.976
Na	0.037	0.021	0.023	0.028	0.031	0.023	0.037
P	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Rb	0.005	0	0.006	0.006	0.009	0.008	0.008
Cs	0.000	0	0	0	0.000	0.000	0.000
An	0	0	0	0	0	0	0
Ab	3.619	2.1079	2.286	2.7622	3.0821	2.325	3.637
Or	96.380	97.892	97.713	97.237	96.918	97.675	96.363

Microprobe analyses of all mica samples. All mica analyses were calculated based on 24 anions.

Usakos micas	U4m-1	U4m-2	U4m-3	U4m-4	U4m-5	U4m-6	U4m-7	U4m-8
oxide								
SiO_2	46.448	46.500	46.523	46.565	46.784	46.477	46.512	46.554
TiO_2	0.014	0.016	0.015	0.009	0.009	0.008	0.011	0.017
Al_2O_3	35.445	35.610	35.484	34.894	35.363	35.423	35.225	35.432
FeO	0.404	0.383	0.406	0.312	0.356	0.412	0.373	0.336
MnO	0.034	0.045	0.041	0.256	0.133	0.155	0.114	0.171
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.083	0.077	0.082	0.034	0.022	0.023	0.009	0.022
Na_2O	0.282	0.312	0.334	0.543	0.488	0.456	0.438	0.448
K_2O	9.223	9.310	9.282	8.223	8.100	8.326	8.430	8.333
Rb_2O	0.672	0.634	0.649	1.565	1.565	1.776	1.687	1.683
Cs_2O	0.030	0.023	0.025	0.045	0.052	0.062	0.055	0.063
Li_2O calc	1.288	1.291	1.483	1.882	1.943	2.029	2.034	2.107
H_2O	3.348	3.359	3.238	2.984	2.977	2.922	2.909	2.881
F	2.445	2.450	2.720	3.255	3.335	3.445	3.452	3.544
subtotal	99.716	100.010	100.282	100.567	101.127	101.514	101.249	101.591
F=O	1.029	1.032	1.145	1.371	1.404	1.451	1.453	1.492
Total	**98.686**	**98.979**	**99.137**	**99.196**	**99.723**	**100.063**	**99.796**	**100.098**
apfu								
Si	6.181	6.170	6.163					
Ti	0.001	0.002	0.001					
Al	5.559	5.568	5.540	6.170	6.157	6.120	6.138	6.122
Fe	0.045	0.042	0.045	0.001	0.001	0.001	0.001	0.002
Mn	0.004	0.005	0.005	5.449	5.485	5.497	5.478	5.491
Mg	0.000	0.000	0.000	0.035	0.039	0.045	0.041	0.037
Ca	0.012	0.011	0.012	0.029	0.015	0.017	0.013	0.019
Na	0.073	0.080	0.086	0.000	0.000	0.000	0.000	0.000
K	1.566	1.576	1.569	0.005	0.003	0.003	0.001	0.003
Rb	0.070	0.066	0.067	0.139	0.125	0.116	0.112	0.114
Cs	0.002	0.001	0.001	1.390	1.360	1.399	1.419	1.398
Li	0.689	0.689	0.790	0.162	0.161	0.183	0.174	0.173
OH	2.971	2.972	2.861	0.003	0.003	0.003	0.003	0.004
F	1.029	1.028	1.139	1.003	1.029	1.074	1.080	1.114
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.479	4.476	4.544	4.685	4.725	4.755	4.750	4.784
Alkali site	1.722	1.734	1.735	1.699	1.652	1.705	1.710	1.692
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos micas	G1-1	G1-2	G1-3	G3-1	G3-2	G3-3	G4-1
oxide							
SiO_2	46.674	46.663	46.623	46.456	46.554	46.530	46.334
TiO_2	0.013	0.018	0.016	0.009	0.011	0.009	0.091
Al_2O_3	35.677	35.665	35.672	35.445	35.432	35.330	35.512
FeO	0.412	0.393	0.400	0.343	0.334	0.298	0.234
MnO	0.065	0.073	0.065	0.077	0.056	0.052	0.044
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.063	0.049	0.055	0.101	0.091	0.083	0.077
Na_2O	0.345	0.383	0.412	0.334	0.354	0.420	0.431
K_2O	9.772	9.590	9.840	8.435	8.334	8.292	8.512
Rb_2O	0.231	0.226	0.231	2.181	2.233	2.177	2.092
Cs_2O	0.015	0.017	0.014	0.032	0.035	0.041	0.034
Li_2O calc	1.364	1.297	1.294	1.447	1.524	1.528	1.373
H_2O	3.333	3.371	3.377	3.256	3.213	3.206	3.303
F	2.554	2.459	2.454	2.670	2.776	2.782	2.566
subtotal	100.518	100.205	100.453	100.786	100.947	100.748	100.602
F=O	1.075	1.035	1.033	1.124	1.169	1.171	1.080
Total	**99.443**	**99.169**	**99.420**	**99.662**	**99.778**	**99.576**	**99.522**
apfu							
Si	6.162	6.169	6.159	6.163	6.165	6.169	6.150
Ti	0.001	0.002	0.002	0.001	0.001	0.001	0.009
Al	5.551	5.557	5.553	5.541	5.530	5.520	5.555
Fe	0.045	0.043	0.044	0.038	0.037	0.033	0.026
Mn	0.007	0.008	0.007	0.009	0.006	0.006	0.005
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.009	0.007	0.008	0.014	0.013	0.012	0.011
Na	0.088	0.098	0.106	0.086	0.091	0.108	0.111
K	1.646	1.617	1.658	1.427	1.408	1.402	1.441
Rb	0.024	0.023	0.024	0.227	0.232	0.226	0.218
Cs	0.001	0.001	0.001	0.002	0.002	0.002	0.002
Li	0.724	0.690	0.687	0.772	0.811	0.815	0.733
OH	2.934	2.972	2.975	2.880	2.838	2.834	2.923
F	1.066	1.028	1.025	1.120	1.162	1.166	1.077
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.491	4.469	4.452	4.524	4.550	4.543	4.478
Alkali site	1.768	1.747	1.796	1.756	1.745	1.750	1.783
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos micas	G4-2	G4-3	G7-1	G7-2	G7-3
oxide					
SiO_2	46.512	46.448	46.670	46.734	46.734
TiO_2	0.087	0.091	0.022	0.018	0.019
Al_2O_3	35.339	35.412	35.667	35.595	35.673
FeO	0.254	0.224	0.272	0.255	0.274
MnO	0.144	0.188	0.114	0.142	0.133
MgO	0.000	0.000	0.000	0.000	0.000
CaO	0.034	0.094	0.055	0.074	0.057
Na_2O	0.377	0.433	0.236	0.300	0.313
K_2O	8.234	8.320	8.093	7.993	8.032
Rb_2O	2.004	1.981	2.620	2.720	2.892
Cs_2O	0.029	0.027	0.050	0.056	0.057
Li_2O calc	1.397	1.421	1.436	1.374	1.433
H_2O	3.282	3.274	3.277	3.318	3.289
F	2.600	2.633	2.655	2.567	2.650
subtotal	100.293	100.546	101.167	101.146	101.556
F=O	1.095	1.109	1.118	1.081	1.116
Total	**99.198**	**99.437**	**100.049**	**100.065**	**100.440**
apfu					
Si	6.180	6.161	6.172	6.181	6.167
Ti	0.009	0.009	0.002	0.002	0.002
Al	5.534	5.535	5.559	5.548	5.548
Fe	0.028	0.025	0.030	0.028	0.030
Mn	0.016	0.021	0.013	0.016	0.015
Mg	0.000	0.000	0.000	0.000	0.000
Ca	0.005	0.013	0.008	0.010	0.008
Na	0.097	0.111	0.061	0.077	0.080
K	1.396	1.408	1.365	1.348	1.352
Rb	0.209	0.206	0.272	0.282	0.299
Cs	0.002	0.002	0.003	0.003	0.003
Li	0.746	0.758	0.764	0.731	0.760
OH	2.908	2.896	2.890	2.926	2.894
F	1.092	1.104	1.110	1.074	1.106
T-site	8.000	8.000	8.000	8.000	8.000
Oct-site	4.513	4.509	4.540	4.505	4.522
Alkali site	1.708	1.740	1.708	1.721	1.742
OH site	4.000	4.000	4.000	4.000	4.000

Usakos micas	1.7-1	1.7-2	1.7-3	U2-1	U2-2	U2-3	U3-1	U3-2
oxide								
SiO_2	45.930	45.875	45.883	46.623	46.550	46.523	46.478	46.512
TiO_2	0.011	0.013	0.008	0.009	0.012	0.014	0.016	0.019
Al_2O_3	36.324	36.371	36.555	35.450	35.460	35.600	35.556	35.640
FeO	0.367	0.412	0.358	0.090	0.123	0.155	0.344	0.341
MnO	0.055	0.061	0.052	0.024	0.033	0.025	0.044	0.045
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.132	0.114	0.091	0.112	0.134	0.143	0.089	0.112
Na_2O	0.442	0.512	0.433	0.344	0.356	0.400	0.282	0.255
K_2O	10.012	10.111	9.995	9.344	9.134	9.294	9.112	9.120
Rb_2O	0.181	0.194	0.187	0.734	0.689	0.733	0.682	0.709
Cs_2O	0.011	0.009	0.014	0.020	0.022	0.019	0.023	0.025
Li_2O calc	1.556	1.335	1.060	1.483	1.440	1.296	1.413	1.483
H_2O	3.217	3.356	3.532	3.238	3.258	3.358	3.275	3.238
F	2.820	2.512	2.111	2.720	2.660	2.457	2.623	2.720
subtotal	101.058	100.875	100.279	100.191	99.871	100.018	99.937	100.220
F=O	1.187	1.058	0.889	1.145	1.120	1.035	1.104	1.145
Total	**99.871**	**99.817**	**99.390**	**99.045**	**98.751**	**98.983**	**98.833**	**99.074**
apfu								
Si	6.050	6.051	6.071	6.177	6.178	6.169	6.170	6.161
Ti	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002
Al	5.638	5.654	5.700	5.535	5.546	5.563	5.563	5.564
Fe	0.040	0.045	0.040	0.010	0.014	0.017	0.038	0.038
Mn	0.006	0.007	0.006	0.003	0.004	0.003	0.005	0.005
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.019	0.016	0.013	0.016	0.019	0.020	0.013	0.016
Na	0.113	0.131	0.111	0.088	0.092	0.103	0.073	0.065
K	1.682	1.701	1.687	1.579	1.546	1.572	1.543	1.541
Rb	0.019	0.020	0.019	0.076	0.072	0.076	0.071	0.074
Cs	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Li	0.824	0.708	0.564	0.790	0.769	0.691	0.755	0.790
OH	2.825	2.952	3.117	2.860	2.884	2.970	2.899	2.861
F	1.175	1.048	0.883	1.140	1.116	1.030	1.101	1.139
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.560	4.467	4.382	4.517	4.512	4.445	4.532	4.560
Alkali site	1.833	1.869	1.831	1.761	1.730	1.772	1.700	1.697
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos micas	U3-3	U5-1	U5-2	U5-3	U6-1	U6-2	U6-3	U9-1
oxide								
SiO_2	46.632	46.388	46.620	46.553	46.334	46.412	46.355	45.984
TiO_2	0.013	0.009	0.008	0.009	0.012	0.009	0.011	0.011
Al_2O_3	35.344	35.551	35.494	35.376	35.678	35.700	35.667	35.551
FeO	0.337	0.110	0.104	0.093	0.212	0.224	0.209	0.267
MnO	0.040	0.023	0.022	0.019	0.014	0.015	0.020	0.034
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.109	0.067	0.073	0.056	0.073	0.056	0.062	0.045
Na_2O	0.300	0.288	0.303	0.312	0.355	0.365	0.355	0.288
K_2O	9.092	9.494	9.445	9.620	9.444	9.356	9.292	9.343
Rb_2O	0.711	0.595	0.613	0.622	0.723	0.745	0.713	0.755
Cs_2O	0.024	0.019	0.018	0.022	0.041	0.044	0.052	0.063
Li_2O calc	1.342	1.373	1.397	1.413	1.393	1.295	1.469	1.449
H_2O	3.318	3.294	3.289	3.273	3.291	3.356	3.243	3.228
F	2.523	2.566	2.600	2.623	2.595	2.455	2.700	2.672
subtotal	99.785	99.777	99.986	99.991	100.165	100.032	100.148	99.690
F=O	1.062	1.080	1.095	1.104	1.093	1.034	1.137	1.125
Total	**98.723**	**98.696**	**98.891**	**98.887**	**99.073**	**98.998**	**99.011**	**98.565**
apfu								
Si	6.197	6.169	6.184	6.183	6.147	6.159	6.147	6.136
Ti	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	5.535	5.572	5.549	5.537	5.578	5.583	5.574	5.591
Fe	0.037	0.012	0.012	0.010	0.024	0.025	0.023	0.030
Mn	0.005	0.003	0.002	0.002	0.002	0.002	0.002	0.004
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.016	0.010	0.010	0.008	0.010	0.008	0.009	0.006
Na	0.077	0.074	0.078	0.080	0.091	0.094	0.091	0.075
K	1.541	1.611	1.598	1.630	1.598	1.584	1.572	1.590
Rb	0.074	0.062	0.064	0.065	0.075	0.077	0.074	0.079
Cs	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.004
Li	0.717	0.734	0.745	0.755	0.743	0.691	0.783	0.777
OH	2.940	2.921	2.909	2.898	2.911	2.970	2.868	2.873
F	1.060	1.079	1.091	1.102	1.089	1.030	1.132	1.127
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.492	4.491	4.493	4.489	4.495	4.460	4.531	4.539
Alkali site	1.709	1.757	1.751	1.784	1.777	1.766	1.749	1.754
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos micas	U9-2	U9-3	U9B-1	U9B-2	U9B-3	U10B-1	U10B-2	U10B-3
oxide								
SiO_2	46.334	46.372	46.34	46.226	46.412	46.66	46.562	46.623
TiO_2	0.009	0.008	0.014	0.016	0.011	0.02	0.012	0.015
Al_2O_3	35.565	35.612	35.44	35.488	35.6	35.77	35.823	35.76
FeO	0.300	0.282	0.41	0.388	0.393	0.303	0.298	0.289
MnO	0.045	0.031	0.05	0.052	0.048	0.033	0.024	0.028
MgO	0.000	0.000	0	0	0	0	0	0
CaO	0.051	0.058	0.077	0.067	0.064	0.045	0.051	0.055
Na_2O	0.310	0.292	0.312	0.433	0.393	0.333	0.383	0.364
K_2O	9.235	9.191	9.433	9.312	9.36	9.78	9.662	9.564
Rb_2O	0.800	0.820	0.733	0.735	0.765	0.44	0.512	0.435
Cs_2O	0.055	0.070	0.056	0.062	0.054	0.025	0.022	0.023
Li_2O calc	1.393	1.483	1.447	1.363	1.483	1.288	1.219	1.215
H_2O	3.282	3.230	3.251	3.302	3.243	3.382	3.423	3.423
F	2.595	2.720	2.67	2.552	2.72	2.445	2.346	2.34
subtotal	99.975	100.170	100.233	99.996	100.546	100.524	100.337	100.134
F=O	1.093	1.145	1.124	1.075	1.145	1.029	0.988	0.985
Total	**98.882**	**99.024**	**99.108**	**98.921**	**99.401**	**99.494**	**99.350**	**99.148**
apfu								
Si	6.159	6.154	6.155	6.146	6.142	6.163	6.158	6.170
Ti	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001
Al	5.571	5.570	5.547	5.560	5.552	5.568	5.583	5.577
Fe	0.033	0.031	0.046	0.043	0.043	0.033	0.033	0.032
Mn	0.005	0.003	0.006	0.006	0.005	0.004	0.003	0.003
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.007	0.008	0.011	0.010	0.009	0.006	0.007	0.008
Na	0.080	0.075	0.080	0.112	0.101	0.085	0.098	0.093
K	1.566	1.556	1.598	1.579	1.580	1.648	1.630	1.615
Rb	0.083	0.085	0.076	0.077	0.079	0.046	0.053	0.045
Cs	0.003	0.004	0.003	0.004	0.003	0.001	0.001	0.001
Li	0.745	0.792	0.773	0.729	0.789	0.684	0.648	0.647
OH	2.909	2.859	2.879	2.927	2.862	2.979	3.019	3.021
F	1.091	1.141	1.121	1.073	1.138	1.021	0.981	0.979
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.514	4.550	4.527	4.486	4.534	4.454	4.426	4.431
Alkali site	1.739	1.728	1.769	1.781	1.772	1.786	1.790	1.762
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos micas	U10A1-1	U10A1-2	U10A1-3	U10C-b-1	U10C-b-2	U10C-b-3	U11-b-1	U11-b-2
oxide								
SiO_2	45.543	45.387	45.609	45.700	45.645	45.764	46.098	45.768
TiO_2	0.000	0.000	0.008	0.012	0.009	0.008	0.009	0.012
Al_2O_3	35.788	35.754	35.800	35.788	35.870	35.855	35.897	36.009
FeO	0.455	0.393	0.303	0.523	0.408	0.378	0.342	0.418
MnO	0.078	0.100	0.093	0.054	0.076	0.052	0.054	0.041
MgO	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.014	0.019	0.023	0.054	0.033	0.028	0.034	0.030
Na_2O	0.540	0.565	0.499	0.388	0.405	0.366	0.444	0.453
K_2O	9.220	9.566	9.666	9.556	9.654	9.542	9.345	9.421
Rb_2O	0.212	0.228	0.200	0.055	0.061	0.052	0.066	0.065
Cs_2O	0.028	0.027	0.024	0.042	0.044	0.051	0.042	0.033
Li_2O calc	1.060	1.047	1.060	0.978	1.030	0.919	0.907	0.851
H_2O	3.469	3.474	3.476	3.531	3.497	3.572	3.601	3.630
F	2.112	2.092	2.112	1.987	2.066	1.896	1.877	1.789
subtotal	98.529	98.653	98.874	98.668	98.798	98.483	98.716	98.520
F=O	0.889	0.881	0.889	0.837	0.870	0.798	0.790	0.753
Total	**97.640**	**97.772**	**97.984**	**97.832**	**97.928**	**97.685**	**97.926**	**97.767**
apfu								
Si	6.110	6.096	6.110	6.128	6.116	6.140	6.157	6.130
Ti	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Al	5.659	5.659	5.652	5.655	5.664	5.669	5.650	5.684
Fe	0.051	0.044	0.034	0.059	0.046	0.042	0.038	0.047
Mn	0.009	0.011	0.011	0.006	0.009	0.006	0.006	0.005
Mg	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.002	0.003	0.003	0.008	0.005	0.004	0.005	0.004
Na	0.140	0.147	0.130	0.101	0.105	0.095	0.115	0.118
K	1.578	1.639	1.652	1.635	1.650	1.633	1.592	1.610
Rb	0.022	0.024	0.021	0.006	0.006	0.005	0.007	0.007
Cs	0.002	0.002	0.001	0.002	0.003	0.003	0.002	0.002
Li	0.572	0.566	0.571	0.527	0.555	0.496	0.487	0.458
OH	3.104	3.111	3.105	3.157	3.125	3.196	3.207	3.242
F	0.896	0.888	0.895	0.843	0.875	0.804	0.793	0.758
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.403	4.376	4.379	4.377	4.390	4.353	4.340	4.325
Alkali site	1.744	1.814	1.807	1.751	1.769	1.741	1.721	1.740
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos micas	U11-b-3	U13b-1	U13b-2	U13b-3	U16A-1	U16A-2	U16A-3	CZ2-1
oxide								
SiO_2	45.776	46.005	45.896	45.799	45.556	45.954	45.843	38.500
TiO_2	0.022	0.009	0.000	0.006	0.021	0.006	0.015	0.766
Al_2O_3	35.885	36.004	35.874	35.750	35.778	35.984	36.120	22.982
FeO	0.444	0.354	0.366	0.354	0.420	0.383	0.324	16.760
MnO	0.048	0.065	0.067	0.075	0.055	0.038	0.065	0.144
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.566
CaO	0.390	0.278	0.300	0.282	0.222	0.293	0.245	0.096
Na_2O	0.487	0.523	0.344	0.420	0.378	0.345	0.312	0.344
K_2O	9.337	9.450	9.440	9.200	8.780	9.009	8.540	9.230
Rb_2O	0.082	0.050	0.048	0.045	1.430	1.337	1.230	0.025
Cs_2O	0.054	0.045	0.041	0.053	0.034	0.031	0.023	0.000
Li_2O calc	0.899	1.066	1.047	1.060	0.915	1.140	0.680	0.981
H_2O	3.604	3.508	3.499	3.479	3.569	3.453	3.757	3.223
F	1.865	2.120	2.092	2.111	1.890	2.230	1.510	1.991
subtotal	98.893	99.477	99.014	98.634	99.048	100.203	98.663	102.608
F=O	0.785	0.893	0.881	0.889	0.796	0.939	0.636	0.838
Total	**98.108**	**98.584**	**98.133**	**97.745**	**98.252**	**99.264**	**98.028**	**101.769**
apfu								
Si	6.118	6.114	6.130	6.132	6.120	6.111	6.148	5.542
Ti	0.002	0.001	0.000	0.001	0.002	0.001	0.002	0.083
Al	5.652	5.639	5.647	5.641	5.664	5.640	5.708	3.899
Fe	0.050	0.039	0.041	0.040	0.047	0.043	0.036	2.017
Mn	0.005	0.007	0.008	0.009	0.006	0.004	0.007	0.018
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.623
Ca	0.056	0.040	0.043	0.040	0.032	0.042	0.035	0.015
Na	0.126	0.135	0.089	0.109	0.098	0.089	0.081	0.096
K	1.592	1.602	1.608	1.571	1.505	1.528	1.461	1.695
Rb	0.009	0.005	0.005	0.005	0.151	0.139	0.129	0.003
Cs	0.003	0.003	0.002	0.003	0.002	0.002	0.001	0.000
Li	0.483	0.570	0.562	0.571	0.494	0.610	0.367	0.568
OH	3.212	3.109	3.116	3.106	3.197	3.062	3.359	3.094
F	0.788	0.891	0.884	0.894	0.803	0.938	0.640	0.906
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.311	4.371	4.388	4.393	4.334	4.408	4.268	5.750
Alkali site	1.786	1.784	1.748	1.729	1.787	1.800	1.708	1.808
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos micas	CZ3A-1	CZ3A-2	CZ3A-3	CZ3B-1	CZ3B-2	CZ3B-3	CZ4-1	CZ4-2
oxide								
SiO_2	46.556	46.233	46.311	46.366	46.282	46.477	46.556	46.452
TiO_2	0.012	0.014	0.011	0.015	0.019	0.017	0.009	0.011
Al_2O_3	36.673	36.589	36.654	36.634	36.557	36.341	36.674	36.777
FeO	0.322	0.314	0.298	0.255	0.231	0.334	0.355	0.365
MnO	0.044	0.041	0.045	0.041	0.037	0.065	0.054	0.075
MgO	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000
CaO	0.112	0.089	0.092	0.088	0.082	0.099	0.144	0.148
Na_2O	0.282	0.255	0.273	0.337	0.383	0.345	0.433	0.373
K_2O	9.983	10.011	10.032	9.892	10.001	9.933	9.873	9.778
Rb_2O	0.114	0.121	0.109	0.122	0.132	0.124	0.191	0.201
Cs_2O	0.009	0.011	0.013	0.012	0.014	0.011	0.007	0.009
Li_2O calc	1.218	1.291	1.211	1.265	1.213	1.218	1.354	1.294
H_2O	3.464	3.394	3.453	3.421	3.449	3.446	3.387	3.420
F	2.344	2.450	2.334	2.412	2.338	2.345	2.540	2.454
subtotal	101.132	100.813	100.836	100.860	100.738	100.768	101.577	101.357
F=O	0.987	1.032	0.983	1.016	0.984	0.987	1.069	1.033
Total	**100.145**	**99.782**	**99.853**	**99.844**	**99.754**	**99.780**	**100.508**	**100.324**
apfu								
Si	6.104	6.087	6.093	6.093	6.092	6.116	6.083	6.079
Ti	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001
Al	5.667	5.678	5.683	5.673	5.671	5.636	5.647	5.672
Fe	0.035	0.035	0.033	0.028	0.025	0.037	0.039	0.040
Mn	0.005	0.005	0.005	0.005	0.004	0.007	0.006	0.008
Mg	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000
Ca	0.016	0.013	0.013	0.012	0.012	0.014	0.020	0.021
Na	0.072	0.065	0.070	0.086	0.098	0.088	0.110	0.095
K	1.670	1.681	1.684	1.658	1.679	1.667	1.645	1.632
Rb	0.012	0.012	0.011	0.013	0.014	0.013	0.020	0.021
Cs	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
Li	0.642	0.684	0.641	0.668	0.642	0.645	0.712	0.681
OH	3.028	2.980	3.029	2.998	3.027	3.024	2.951	2.984
F	0.972	1.020	0.971	1.002	0.973	0.976	1.049	1.016
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.454	4.489	4.455	4.469	4.436	4.444	4.487	4.482
Alkali site	1.769	1.772	1.778	1.770	1.803	1.783	1.795	1.769
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos micas	CZ4-3	CZ6-1	CZ6-2	CZ6-3	OP1-1	OP1-2	OP1-3
oxide							
SiO_2	46.444	46.343	46.400	46.399	46.445	46.500	46.434
TiO_2	0.013	0.022	0.016	0.013	0.013	0.015	0.016
Al_2O_3	36.723	36.678	36.562	36.566	35.450	35.477	35.388
FeO	0.359	0.377	0.345	0.365	0.512	0.477	0.476
MnO	0.033	0.045	0.043	0.063	0.033	0.026	0.030
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.121	0.083	0.093	0.080	0.092	0.089	0.093
Na_2O	0.333	0.282	0.303	0.316	0.300	0.282	0.244
K_2O	9.673	9.777	9.870	9.845	9.883	9.912	9.992
Rb_2O	0.188	0.235	0.243	0.247	0.260	0.234	0.303
Cs_2O	0.015	0.012	0.011	0.010	0.015	0.016	0.018
Li_2O calc	1.365	1.143	1.216	1.288	1.373	1.311	1.211
H_2O	3.367	3.498	3.452	3.407	3.306	3.347	3.402
F	2.555	2.235	2.341	2.445	2.566	2.478	2.334
subtotal	101.189	100.730	100.894	101.044	100.248	100.164	99.941
F=O	1.076	0.941	0.986	1.029	1.080	1.043	0.983
Total	**100.113**	**99.789**	**99.909**	**100.014**	**99.168**	**99.121**	**98.958**
apfu							
Si	6.085	6.099	6.101	6.095	6.160	6.168	6.177
Ti	0.001	0.002	0.002	0.001	0.001	0.001	0.002
Al	5.670	5.688	5.666	5.661	5.541	5.546	5.548
Fe	0.039	0.041	0.038	0.040	0.057	0.053	0.053
Mn	0.004	0.005	0.005	0.007	0.004	0.003	0.003
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.017	0.012	0.013	0.011	0.013	0.013	0.013
Na	0.085	0.072	0.077	0.080	0.077	0.073	0.063
K	1.617	1.641	1.656	1.650	1.672	1.677	1.696
Rb	0.019	0.024	0.025	0.025	0.027	0.024	0.032
Cs	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Li	0.719	0.605	0.643	0.680	0.732	0.699	0.648
OH	2.941	3.070	3.027	2.984	2.924	2.961	3.018
F	1.058	0.930	0.973	1.016	1.076	1.039	0.982
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	4.518	4.441	4.454	4.484	4.495	4.471	4.431
Alkali site	1.738	1.750	1.772	1.767	1.790	1.788	1.804
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos Biotite	CZ2-2	CZ2-3	CZ1B-1	CZ1B-2	CZ1B-3	CZ2-1	CZ2-2	CZ2-3
oxide								
SiO_2	38.65	38.77	46.110	45.956	45.934	38.550	38.423	38.634
TiO_2	0.833	0.844	0.009	0.000	0.011	0.760	0.686	0.634
Al_2O_3	23.223	23.191	36.773	36.585	36.623	23.343	23.002	23.430
FeO	16.556	16.45	0.282	0.277	0.256	16.340	16.556	16.723
MnO	0.155	0.143	0.036	0.045	0.037	0.101	0.123	0.153
MgO	7.512	7.4	0.000	0.000	0.000	7.454	7.679	7.660
CaO	0.1	0.089	0.121	0.089	0.091	0.082	0.082	0.077
Na_2O	0.292	0.311	0.383	0.355	0.409	0.330	0.412	0.383
K_2O	9.455	9.4	10.012	9.914	9.994	8.930	9.034	8.783
Rb_2O	0.023	0.022	0.223	0.253	0.247	0.023	0.021	0.024
Cs_2O	0	0	0.014	0.013	0.011	0.000	0.000	0.008
Li_2O calc	0.916	0.988	1.449	1.421	1.366	0.916	0.995	1.009
H_2O	3.284	3.233	3.307	3.303	3.341	3.265	3.206	3.225
F	1.891	2.002	2.672	2.633	2.556	1.891	2.013	2.034
subtotal	102.890	102.843	101.391	100.843	100.876	101.985	102.232	102.776
F=O	0.796	0.843	1.125	1.109	1.076	0.796	0.848	0.856
Total	**102.094**	**102.000**	**100.266**	**99.735**	**99.799**	**101.189**	**101.384**	**101.920**
apfu								
Si	5.546	5.560	6.047	6.057	6.052	5.556	5.540	5.532
Ti	0.090	0.091	0.001	0.000	0.001	0.082	0.074	0.068
Al	3.927	3.920	5.683	5.683	5.686	3.965	3.908	3.954
Fe	1.986	1.973	0.031	0.031	0.028	1.969	1.996	2.002
Mn	0.019	0.017	0.004	0.005	0.004	0.012	0.015	0.019
Mg	1.606	1.581	0.000	0.000	0.000	1.601	1.650	1.634
Ca	0.015	0.014	0.017	0.013	0.013	0.013	0.013	0.012
Na	0.081	0.086	0.097	0.091	0.104	0.092	0.115	0.106
K	1.730	1.720	1.675	1.667	1.680	1.642	1.661	1.604
Rb	0.003	0.002	0.023	0.026	0.026	0.003	0.002	0.003
Cs	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000
Li	0.528	0.570	0.764	0.753	0.724	0.531	0.577	0.581
OH	3.142	3.092	2.892	2.903	2.935	3.138	3.082	3.079
F	0.858	0.908	1.108	1.097	1.065	0.862	0.918	0.921
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	5.702	5.712	4.529	4.528	4.495	5.717	5.760	5.791
Alkali site	1.830	1.822	1.813	1.797	1.823	1.749	1.792	1.726
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos Lepidolite	L1-1	L1-2	L1-3	L2-1	L2-2	L2-3	L3-1	L3-2
oxide								
SiO_2	51.447	51.543	51.609	50.956	50.895	50.994	51.002	50.934
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	28.334	27.892	27.882	27.667	27.595	27.622	28.112	28.134
FeO	0.022	0.029	0.031	0.014	0.009	0.012	0.009	0.011
MnO	0.013	0.019	0.017	0.009	0.013	0.011	0.009	0.008
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.033	0.024	0.026	0.013	0.019	0.017	0.022	0.015
Na_2O	0.440	0.455	0.451	0.339	0.312	0.334	0.355	0.299
K_2O	8.223	8.109	8.213	8.312	8.500	8.312	8.223	8.456
Rb_2O	2.430	2.388	2.443	2.312	2.277	2.430	2.225	2.415
Cs_2O	0.083	0.109	0.104	0.091	0.088	0.103	0.112	0.109
Li_2O calc	5.637	5.175	5.512	5.749	5.289	5.308	5.743	5.850
H_2O	1.144	1.322	1.184	1.033	1.221	1.219	1.058	1.014
F	7.445	6.980	7.320	7.556	7.096	7.115	7.550	7.656
subtotal	105.251	104.045	104.792	104.051	103.314	103.477	104.420	104.901
F=O	3.135	2.939	3.082	3.181	2.988	2.996	3.179	3.224
Total	**102.116**	**101.106**	**101.710**	**100.869**	**100.326**	**100.481**	**101.241**	**101.677**
apfu								
Si	6.602	6.675	6.650	6.622	6.658	6.660	6.596	6.578
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	4.285	4.257	4.234	4.237	4.254	4.251	4.285	4.282
Fe	0.002	0.003	0.003	0.002	0.001	0.001	0.001	0.001
Mn	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.005	0.003	0.004	0.002	0.003	0.002	0.003	0.002
Na	0.109	0.114	0.113	0.085	0.079	0.085	0.089	0.075
K	1.346	1.340	1.350	1.378	1.418	1.385	1.357	1.393
Rb	0.244	0.242	0.247	0.235	0.233	0.249	0.226	0.244
Cs	0.005	0.006	0.006	0.005	0.005	0.006	0.006	0.006
Li	2.909	2.695	2.856	3.004	2.782	2.788	2.987	3.038
OH	0.979	1.142	1.018	0.895	1.065	1.062	0.912	0.873
F	3.021	2.858	2.982	3.105	2.935	2.938	3.088	3.127
T-site	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	5.799	5.632	5.744	5.865	5.696	5.702	5.869	5.901
Alkali site	1.709	1.706	1.718	1.706	1.738	1.726	1.680	1.720
OH site	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Usakos Lepidolite	L3-3	U4M-I-1	U4M-I-2	U4M-I-3	U4M-I-4	U4M-I-5
oxide						
SiO_2	50.880	51.223	51.234	51.443	51.223	51.114
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	28.430	28.225	27.982	28.044	28.014	27.922
FeO	0.011	0.034	0.054	0.052	0.062	0.059
MnO	0.009	0.024	0.031	0.028	0.024	0.043
MgO	0.000	0.000	0.000	0.000	0.000	0.000
CaO	0.019	0.000	0.000	0.011	0.000	0.032
Na_2O	0.365	0.383	0.411	0.398	0.409	0.411
K_2O	8.300	8.244	8.330	8.412	8.422	8.342
Rb_2O	2.366	1.776	1.778	1.877	1.900	1.834
Cs_2O	0.126	0.121	0.098	0.122	0.132	0.133
Li_2O calc	5.753	6.067	5.849	5.970	5.514	5.307
H_2O	1.066	0.938	1.022	0.989	1.166	1.242
F	7.560	7.870	7.655	7.774	7.322	7.114
subtotal	104.885	104.906	104.444	105.120	104.187	103.553
F=O	3.183	3.314	3.223	3.273	3.083	2.995
Total	**101.701**	**101.592**	**101.221**	**101.846**	**101.104**	**100.557**
apfu						
Si	6.562					
Ti	0.000	6.578	6.607	6.601	6.626	6.644
Al	4.321	0.000	0.000	0.000	0.000	0.000
Fe	0.001	4.272	4.253	4.241	4.271	4.277
Mn	0.001	0.004	0.006	0.006	0.007	0.006
Mg	0.000	0.003	0.003	0.003	0.003	0.005
Ca	0.003	0.000	0.000	0.000	0.000	0.000
Na	0.091	0.000	0.000	0.002	0.000	0.004
K	1.365	0.095	0.103	0.099	0.103	0.104
Rb	0.239	1.350	1.370	1.377	1.390	1.383
Cs	0.007	0.179	0.180	0.189	0.193	0.187
Li	2.984	0.007	0.005	0.007	0.007	0.007
OH	0.917	3.133	3.033	3.080	2.868	2.774
F	3.083	0.803	0.879	0.846	1.005	1.076
T-site	8.000	8.000	8.000	8.000	8.000	8.000
Oct-site	5.869	5.990	5.902	5.931	5.775	5.707
Alkali site	1.705	1.631	1.658	1.673	1.692	1.685
OH site	4.000	3.999	4.001	4.001	4.001	4.000

Microprobe data for all Garnet.

Microprobe analyses of garnet were calculated based on 12 oxygen.

Standards for EMP analyses for **garnet** Acceleration potential: 15-20 kV Beam current: 15-22 nA Count times: 45 seconds per spot	
Clinopyroxene, "Cpx-26-ano"	Si
Andalusite, Minas Gerais	Al
Fayalite	Fe
Spessartine	Mn
Clinopyroxene, "Cpx-26-ano"	Mg
Clinopyroxene, "Cpx-26-ano"	Ca

Other MAN standards used:

Al_2O_3, synthetic

Hematite, Elba

MgO, synthetic

PbO, synthetic

V_2O_5, synthetic

ZnO, synthetic

ZrO_2, synthetic

	G1-1	G1-2	G1-3	G1-4	G1-5
oxide					
SiO_2	36.55	36.523	36.494	36.566	36.44
Al_2O_3	20.556	20.623	20.556	20.484	20.677
FeO	24.334	24.567	24.5	24.555	24.412
MnO	18.567	18.556	18.91	18.813	18.556
MgO	0.034	0.044	0.051	0.023	0.03
CaO	0.144	0.171	0.133	0.156	0.109
Total	100.185	100.484	100.644	100.597	100.224
apfu					
Si	3.01	3.002	2.999	3.005	3.001
Al	1.995	1.998	1.991	1.984	2.007
Fe	1.676	1.688	1.683	1.688	1.681
Mn	1.295	1.29	1.316	1.309	1.294
Mg	0.004	0.005	0.006	0.003	0.004
Ca	0.013	0.015	0.012	0.014	0.01
x-site	2.988	3.000	3.017	3.014	2.988
y-site	1.995	1.997	1.991	1.984	2.007
z-site	3.01	3.002	2.999	3.005	3.001

Microprobe analyses of all Columbite-Tantalite.

Standards for EMP analyses for **Nb-Ta Oxides** Acceleration potential: 15-20 kV Beam current: 15-22 nA Count times: 45 seconds per spot	
Tantalite-(Mn), Himalaya Pegmatite CA Microlite Harding Pegmatite NM	Ta
$YNbO_4$, synthetic	Nb
Microlite Harding Pegmatite NM	Ca
Microlite Harding Pegmatite NM	Na
Rutile, synthetic	Ti
Corundum, synthetic	Al
Hematite, Elba, Italy	Fe
Tantalite-(Mn), Himalaya Pegmatite CA	Mn
Cassiterite	Sn
$CaWO_4$, synthetic	W
Samarskite, Afghan	U
Bismuto-tantalite,	Bi
Clinopyroxene, “Cpx-26-ano”	Si
Other MAN standards used: Al_2O_3, synthetic Hematite, Elba MgO, synthetic PbO, synthetic V_2O_5, synthetic ZnO, synthetic ZrO_2, synthetic	

Columbite-Tantalite analyses calculated based on 6 oxygen

Columbite	NT-2-1	NT-2-2	NT-2-3	NT3-1	NT3-2
oxide					
Ta_2O_5	21.091	20.982	21.003	21.891	21.781
Nb_2O_5	60.223	60.290	60.113	59.111	58.980
CaO	0.000	0.000	0.000	0.000	0.000
Na_2O	0.000	0.000	0.000	0.000	0.000
TiO_2	0.000	0.000	0.000	0.000	0.000
Al_2O_3	0.000	0.000	0.000	0.000	0.000
FeO	12.520	12.232	12.191	11.450	11.234
MnO	7.110	7.445	7.622	8.230	8.430
SnO_2	0.008	0.000	0.012	0.009	0.013
WO_3	0.013	0.009	0.011	0.014	0.021
UO_2	0.021	0.012	0.014	0.010	0.009
Bi_2O_3	0.000	0.000	0.000	0.000	0.000
SiO_2	0.009	0.013	0.022	0.023	0.011
Total	**100.995**	**100.983**	**100.988**	**100.738**	**100.479**
apfu					
Ta	0.348	0.346	0.346	0.363	0.362
Nb	1.651	1.652	1.648	1.631	1.632
Ca	0.000	0.000	0.000	0.000	0.000
Na	0.000	0.000	0.000	0.000	0.000
Ti	0.000	0.000	0.000	0.000	0.000
Al	0.000	0.000	0.000	0.000	0.000
Fe	0.635	0.620	0.618	0.584	0.575
Mn	0.365	0.382	0.391	0.425	0.437
Sn	0.000	0.000	0.000	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000
U	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000
Si	0.001	0.001	0.001	0.001	0.001

Columbite	NT3-3	CZ-1B-21-1	CZ-1B-21-2	CZ-1B-21-3
oxide				
Ta_2O_5	21.781	22.092	22.113	22.255
Nb_2O_5	58.730	58.770	58.656	58.720
CaO	0.000	0.000	0.000	0.000
Na_2O	0.000	0.000	0.000	0.000
TiO_2	0.000	0.000	0.000	0.000
Al_2O_3	0.000	0.000	0.000	0.000
FeO	11.560	12.009	12.231	12.145
MnO	8.341	7.123	7.091	7.220
SnO_2	0.021	0.011	0.009	0.009
WO_3	0.043	0.010	0.014	0.009
UO_2	0.012	0.011	0.014	0.013
Bi_2O_3	0.000	0.000	0.000	0.000
SiO_2	0.051	0.012	0.022	0.009
Total	**100.539**	**100.038**	**100.150**	**100.380**
apfu				
Ta	0.362	0.369	0.370	0.371
Nb	1.624	1.634	1.630	1.629
Ca	0.000	0.000	0.000	0.000
Na	0.000	0.000	0.000	0.000
Ti	0.000	0.000	0.000	0.000
Al	0.000	0.000	0.000	0.000
Fe	0.591	0.618	0.629	0.623
Mn	0.432	0.371	0.369	0.375
Sn	0.001	0.000	0.000	0.000
W	0.001	0.000	0.000	0.000
U	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000
Si	0.003	0.001	0.001	0.001

Tantalite	L1-6	L1-7	L1-8	L1-9	L1-10	L1-2-2-1	L1-2-2-2
oxide							
Ta_2O_5	84.340	83.970	84.100	84.300	84.280	83.453	83.344
Nb_2O_5	3.210	3.190	3.270	3.110	3.220	3.452	3.389
CaO	0.000	0.000	0.000	0.000	0.000	0.133	0.236
Na_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TiO_2	0.010	0.010	0.000	0.000	0.000	0.130	0.091
Al_2O_3	0.020	0.010	0.010	0.000	0.000	0.012	0.033
FeO	14.000	14.060	13.900	0.870	0.790	0.344	0.393
MnO	0.780	0.880	0.860	13.220	13.340	13.029	12.992
SnO_2	0.010	0.010	0.010	0.010	0.010	0.191	0.133
WO_3	0.000	0.000	0.010	0.010	0.010	0.000	0.000
UO_2	0.010	0.000	0.010	0.010	0.010	0.022	0.033
Bi_2O_3	0.000	0.000	0.000	0.000	0.000	0.009	0.008
SiO_2	0.000	0.000	0.010	0.020	0.020	0.033	0.025
Total	**102.380**	**102.130**	**102.180**	**101.550**	**101.680**	**100.808**	**100.677**
apfu							
Ta	1.875	1.871	1.873	1.889	1.885	1.877	1.877
Nb	0.119	0.118	0.121	0.116	0.120	0.129	0.127
Ca	0.000	0.000	0.000	0.000	0.000	0.012	0.021
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ti	0.001	0.001	0.000	0.000	0.000	0.008	0.006
Al	0.002	0.001	0.001	0.000	0.000	0.001	0.003
Fe	0.957	0.963	0.952	0.060	0.054	0.024	0.027
Mn	0.054	0.061	0.060	0.923	0.929	0.913	0.911
Sn	0.000	0.000	0.000	0.000	0.000	0.006	0.004
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Si	0.000	0.000	0.001	0.002	0.002	0.003	0.002

Tantalite	L1-2-2-3	L1-2-3-1	L1-2-3-2	L1-2-3-3	L1-2-4-1	L1-2-4-2	L1-2-4-3	L1-2-9-1
oxide								
Ta_2O_5	83.181	82.891	83.111	83.022	83.093	83.016	83.009	83.345
Nb_2O_5	3.440	3.445	3.540	3.642	3.730	3.783	3.556	3.312
CaO	0.098	0.233	0.412	0.181	0.092	0.078	0.092	0.122
Na_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TiO_2	0.088	0.060	0.060	0.074	0.055	0.047	0.056	0.022
Al_2O_3	0.028	0.019	0.020	0.017	0.000	0.012	0.000	0.000
FeO	0.404	0.434	0.444	0.472	0.678	0.623	0.650	1.333
MnO	13.121	13.410	13.091	13.188	12.889	12.782	12.872	12.112
SnO_2	0.091	0.072	0.062	0.053	0.022	0.043	0.032	0.009
WO_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UO_2	0.034	0.019	0.016	0.020	0.018	0.043	0.028	0.009
Bi_2O_3	0.000	0.000	0.007	0.008	0.011	0.009	0.008	0.000
SiO_2	0.044	0.021	0.019	0.013	0.033	0.037	0.028	0.033
Total	**100.529**	**100.604**	**100.782**	**100.690**	**100.621**	**100.473**	**100.331**	**100.297**
apfu								
Ta	1.876	1.867	1.867	1.867	1.871	1.872	1.876	1.888
Nb	0.129	0.129	0.132	0.136	0.140	0.142	0.134	0.125
Ca	0.009	0.021	0.036	0.016	0.008	0.007	0.008	0.011
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ti	0.005	0.004	0.004	0.005	0.003	0.003	0.004	0.001
Al	0.003	0.002	0.002	0.002	0.000	0.001	0.000	0.000
Fe	0.028	0.030	0.031	0.033	0.047	0.043	0.045	0.093
Mn	0.922	0.941	0.916	0.924	0.904	0.898	0.906	0.855
Sn	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.000
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Si	0.004	0.002	0.002	0.001	0.003	0.003	0.002	0.003

Tantalite	L1-2-9-3	L1-5-3-1	L1-5-8-1	L1-10-3	L1-10-5	L1-10-6	L1-10-7	L1-11-4
oxide								
Ta_2O_5	83.399	82.872	83.126	83.023	82.877	83.112	82.892	82.872
Nb_2O_5	3.412	3.765	3.670	3.093	3.223	3.093	3.334	3.220
CaO	0.089	0.045	0.044	0.000	0.011	0.000	0.000	0.000
Na_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TiO_2	0.033	0.017	0.013	0.009	0.011	0.017	0.022	0.011
Al_2O_3	0.000	0.000	0.023	0.012	0.009	0.000	0.013	0.022
FeO	1.464	1.505	1.654	1.810	1.710	2.223	1.891	1.981
MnO	12.091	11.871	11.891	12.430	11.912	11.577	11.778	12.119
SnO_2	0.021	0.022	0.016	0.020	0.022	0.033	0.041	0.033
WO_3	0.000	0.000	0.045	0.012	0.018	0.014	0.022	0.009
UO_2	0.012	0.013	0.022	0.017	0.023	0.034	0.023	0.009
Bi_2O_3	0.000	0.000	0.015	0.017	0.021	0.019	0.020	0.000
SiO_2	0.021	0.011	0.044	0.022	0.053	0.023	0.028	0.029
Total	**100.542**	**100.121**	**100.563**	**100.465**	**99.890**	**100.145**	**100.064**	**100.305**
apfu								
Ta	1.884	1.877	1.874	1.879	1.886	1.889	1.882	1.877
Nb	0.128	0.142	0.138	0.116	0.122	0.117	0.126	0.121
Ca	0.008	0.004	0.004	0.000	0.001	0.000	0.000	0.000
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ti	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	0.000	0.000	0.002	0.001	0.001	0.000	0.001	0.002
Fe	0.102	0.105	0.115	0.126	0.120	0.155	0.132	0.138
Mn	0.851	0.838	0.835	0.876	0.844	0.819	0.833	0.855
Sn	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
W	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
U	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Si	0.002	0.001	0.004	0.002	0.004	0.002	0.002	0.002

Tantalite	L1-11-5	L1-11-8	L1-14-1	L1-14-3	L1-14-4	L1-14-5	L1-14--2	L1-16-5
oxide								
Ta_2O_5	83.283	83.728	83.244	83.145	83.650	83.643	83.410	83.410
Nb_2O_5	2.792	3.331	3.112	3.552	3.191	3.091	3.023	3.023
CaO	0.000	0.008	0.012	0.022	0.018	0.013	0.009	0.009
Na_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TiO_2	0.017	0.008	0.011	0.014	0.018	0.011	0.009	0.009
Al_2O_3	0.028	0.000	0.009	0.022	0.019	0.032	0.023	0.023
FeO	1.711	1.330	1.440	1.678	1.234	1.400	1.210	1.334
MnO	12.421	12.100	11.981	11.878	11.910	11.998	12.155	12.456
SnO_2	0.012	0.008	0.011	0.031	0.027	0.022	0.019	0.019
WO_3	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UO_2	0.021	0.007	0.000	0.008	0.012	0.011	0.000	0.000
Bi_2O_3	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SiO_2	0.045	0.033	0.033	0.038	0.034	0.023	0.022	0.022
Total	**100.362**	**100.553**	**99.853**	**100.388**	**100.113**	**100.244**	**99.880**	**100.305**
apfu								
Ta	1.889	1.894	1.897	1.879	1.902	1.900	1.902	1.893
Nb	0.105	0.125	0.118	0.133	0.121	0.117	0.115	0.114
Ca	0.000	0.001	0.001	0.002	0.002	0.001	0.001	0.001
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ti	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	0.003	0.000	0.001	0.002	0.002	0.003	0.002	0.002
Fe	0.119	0.092	0.101	0.117	0.086	0.098	0.085	0.093
Mn	0.878	0.852	0.851	0.836	0.843	0.849	0.863	0.880
Sn	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Si	0.004	0.003	0.003	0.003	0.003	0.002	0.002	0.002

Tantalite	L1-16-6	L1-16-7	L1-16-9	L2-2-1	L2-2-6
oxide					
Ta_2O_5	68.766	68.893	68.230	82.870	81.810
Nb_2O_5	13.760	13.965	12.220	3.445	4.122
CaO	0.000	0.000	0.009	0.000	0.008
Na_2O	0.000	0.000	0.000	0.000	0.000
TiO_2	0.033	0.022	0.012	0.011	0.009
Al_2O_3	0.019	0.000	0.020	0.000	0.000
FeO	7.600	6.984	3.334	1.777	2.540
MnO	8.998	9.313	10.213	12.165	11.656
SnO_2	0.017	0.011	0.010	0.023	0.056
WO_3	0.009	0.014	0.000	0.000	0.000
UO_2	0.000	0.000	0.000	0.009	0.000
Bi_2O_3	0.009	0.013	0.009	0.013	0.009
SiO_2	0.043	0.014	0.023	0.026	0.044
Total	**99.254**	**99.229**	**94.080**	**100.339**	**100.254**
apfu					
Ta	1.467	1.471	1.551	1.875	1.843
Nb	0.488	0.496	0.462	0.130	0.154
Ca	0.000	0.000	0.001	0.000	0.001
Na	0.000	0.000	0.000	0.000	0.000
Ti	0.002	0.001	0.001	0.001	0.001
Al	0.002	0.000	0.002	0.000	0.000
Fe	0.499	0.458	0.233	0.124	0.176
Mn	0.598	0.619	0.723	0.857	0.818
Sn	0.001	0.000	0.000	0.001	0.002
W	0.000	0.000	0.000	0.000	0.000
U	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000
Si	0.003	0.001	0.002	0.002	0.004

Tantalite	L2-2-10	L2-5-1	L2-5-3	L2-5-4	L2-5-10
oxide					
Ta_2O_5	81.233	80.778	81.400	79.956	79.788
Nb_2O_5	4.530	5.120	4.230	5.556	5.334
CaO	0.044	0.011	0.000	0.000	0.009
Na_2O	0.000	0.000	0.000	0.000	0.000
TiO_2	0.013	0.023	0.009	0.013	0.015
Al_2O_3	0.042	0.025	0.025	0.015	0.011
FeO	2.982	3.120	3.120	2.677	3.000
MnO	11.237	11.012	11.045	11.355	11.651
SnO_2	0.036	0.013	0.022	0.009	0.023
WO_3	0.000	0.000	0.000	0.000	0.000
UO_2	0.000	0.000	0.012	0.023	0.037
Bi_2O_3	0.012	0.022	0.021	0.028	0.044
SiO_2	0.098	0.034	0.045	0.036	0.074
Total	**100.227**	**100.158**	**99.929**	**99.668**	**99.986**
apfu					
Ta	1.822	1.810	1.838	1.796	1.786
Nb	0.169	0.191	0.159	0.207	0.198
Ca	0.004	0.001	0.000	0.000	0.001
Na	0.000	0.000	0.000	0.000	0.000
Ti	0.001	0.001	0.001	0.001	0.001
Al	0.004	0.002	0.002	0.001	0.001
Fe	0.206	0.215	0.217	0.185	0.206
Mn	0.785	0.769	0.777	0.794	0.812
Sn	0.001	0.000	0.001	0.000	0.001
W	0.000	0.000	0.000	0.000	0.000
U	0.000	0.000	0.000	0.000	0.001
Bi	0.000	0.000	0.000	0.001	0.001
Si	0.008	0.003	0.004	0.003	0.006

Microprobe analyses for all pyrochlore samples. Calculated on the bases of 7 oxygen.

	L1-1	L1-2	L1-3	L1-4	L1-5	L1-2-1-1	L1-2-1-2	L1-2-1-3
oxide								
Ta_2O_5	73.330	73.560	73.600	73.510	73.360	74.334	74.740	75.009
Nb_2O_5	5.540	5.340	5.330	5.450	5.670	4.894	4.674	4.722
CaO	12.990	13.110	13.230	12.780	12.920	12.720	12.652	12.559
Na_2O	2.560	2.220	2.310	2.670	2.450	2.383	2.292	2.393
TiO_2	0.780	0.820	0.810	0.750	0.650	0.566	0.494	0.532
Al_2O_3	0.020	0.030	0.020	0.070	0.020	0.044	0.034	0.031
FeO	0.280	0.300	0.190	0.220	0.240	0.122	0.091	0.112
MnO	0.430	0.510	0.380	0.420	0.380	0.292	0.182	0.223
SnO_2	0.020	0.050	0.040	0.040	0.060	0.112	0.089	0.092
WO_3	0.440	0.500	0.560	0.650	0.560	0.500	0.293	0.540
UO_2	0.370	0.350	0.290	0.330	0.210	0.123	0.091	0.088
Bi_2O_3	0.000	0.000	0.000	0.000	0.000	0.044	0.070	0.083
SiO_2	0.170	0.200	0.170	0.160	0.110	0.135	0.091	0.081
H2O(calc)	0.635	0.576	0.618	0.639	0.616	0.498	0.551	0.463
F	2.320	2.440	2.350	2.310	2.340	2.554	2.412	2.622
O=F	0.977	1.027	0.989	0.973	0.985	1.075	1.016	1.104
subtotal	99.885	100.006	99.898	99.999	99.586	99.321	98.756	99.550
Total	**98.908**	**98.979**	**98.909**	**99.027**	**98.601**	**98.246**	**97.740**	**98.446**
apfu								
Ta	1.724	1.729	1.731	1.728	1.733	1.773	1.799	1.792
Nb	0.217	0.209	0.208	0.213	0.223	0.194	0.187	0.188
Ca	1.203	1.214	1.226	1.183	1.202	1.195	1.200	1.182
Na	0.429	0.372	0.387	0.447	0.413	0.405	0.393	0.408
Ti	0.051	0.053	0.053	0.049	0.042	0.037	0.033	0.035
Al	0.002	0.003	0.002	0.007	0.002	0.005	0.004	0.003
Fe	0.020	0.022	0.014	0.016	0.017	0.009	0.007	0.008
Mn	0.031	0.037	0.028	0.031	0.028	0.022	0.014	0.017
Sn	0.001	0.002	0.001	0.001	0.002	0.004	0.003	0.003
W	0.010	0.011	0.013	0.015	0.013	0.011	0.007	0.012
U	0.007	0.007	0.006	0.006	0.004	0.002	0.002	0.002
Bi	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002
Si	0.015	0.017	0.015	0.014	0.010	0.012	0.008	0.007
OH	0.366	0.332	0.357	0.368	0.357	0.292	0.325	0.271
F	0.634	0.667	0.643	0.631	0.643	0.708	0.675	0.729

	L1-2-5-1	L1-2-5-2	L1-2-5-3	L1-2-6-1	L1-2-6-2	L1-2-6-3	L1-2-7-1	L1-2-7-2
oxide								
Ta_2O_5	75.000	74.980	75.222	77.672	77.760	77.598	73.677	73.723
Nb_2O_5	3.993	4.033	3.893	2.892	3.009	2.977	4.788	4.876
CaO	12.556	12.620	12.892	11.234	11.650	11.675	13.122	13.098
Na_2O	2.760	2.782	2.672	2.892	2.778	2.834	2.389	2.400
TiO_2	0.340	0.211	0.089	0.061	0.077	0.045	0.221	0.188
Al_2O_3	0.055	0.022	0.011	0.009	0.000	0.000	0.000	0.000
FeO	0.045	0.012	0.023	0.018	0.022	0.031	0.055	0.060
MnO	0.024	0.031	0.029	0.021	0.034	0.028	0.038	0.054
SnO_2	0.044	0.032	0.011	0.012	0.009	0.013	0.020	0.018
WO_3	0.022	0.018	0.016	0.009	0.010	0.013	0.009	0.016
UO_2	0.072	0.052	0.023	0.012	0.022	0.031	0.051	0.027
Bi_2O_3	0.043	0.073	0.034	0.023	0.019	0.019	0.034	0.044
SiO_2	0.077	0.062	0.041	0.055	0.054	0.048	0.022	0.019
H2O(calc)	0.383	0.337	0.343	0.271	0.296	0.278	0.561	0.574
F	2.723	2.810	2.792	2.892	2.867	2.898	2.334	2.312
O=F	1.147	1.183	1.176	1.218	1.207	1.220	0.983	0.973
subtotal	98.137	98.075	98.091	98.073	98.607	98.488	97.321	97.409
Total	**96.990**	**96.892**	**96.916**	**96.855**	**97.400**	**97.268**	**96.339**	**96.435**
apfu								
Ta	1.827	1.832	1.840	1.928	1.916	1.915	1.799	1.798
Nb	0.162	0.164	0.158	0.119	0.123	0.122	0.194	0.198
Ca	1.205	1.215	1.242	1.099	1.131	1.135	1.262	1.259
Na	0.479	0.485	0.466	0.512	0.488	0.499	0.416	0.417
Ti	0.023	0.014	0.006	0.004	0.005	0.003	0.015	0.013
Al	0.006	0.002	0.001	0.001	0.000	0.000	0.000	0.000
Fe	0.003	0.001	0.002	0.001	0.002	0.002	0.004	0.005
Mn	0.002	0.002	0.002	0.002	0.003	0.002	0.003	0.004
Sn	0.002	0.001	0.000	0.000	0.000	0.000	0.001	0.001
W	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.001	0.001	0.000	0.000	0.000	0.001	0.001	0.001
Bi	0.001	0.002	0.001	0.001	0.000	0.000	0.001	0.001
Si	0.007	0.006	0.004	0.005	0.005	0.004	0.002	0.002
OH	0.229	0.202	0.206	0.165	0.179	0.168	0.336	0.343
F	0.771	0.798	0.794	0.835	0.821	0.832	0.663	0.656

	L1-2-7-3	L1-2-8-1	L1-2-8-2	L1-2-8-3	L1-2-9-2	L1-5-1-1	L1-5-1-2	L1-5-1-3
oxide								
Ta_2O_5	73.566	73.412	73.412	73.404	83.006	81.872	81.777	81.712
Nb_2O_5	4.760	4.845	4.900	4.893	2.096	3.556	3.612	3.634
CaO	13.153	12.891	12.902	12.872	10.335	11.091	10.891	10.430
Na_2O	2.342	2.282	2.400	2.273	1.897	2.112	1.871	2.043
TiO_2	0.213	0.133	0.109	0.128	0.455	0.012	0.023	0.018
Al_2O_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FeO	0.048	0.081	0.062	0.055	0.177	0.043	0.026	0.026
MnO	0.060	0.112	0.091	0.123	0.334	0.101	0.084	0.093
SnO_2	0.016	0.018	0.020	0.012	0.033	0.022	0.015	0.017
WO_3	0.016	0.010	0.009	0.012	0.009	0.000	0.006	0.000
UO_2	0.052	0.033	0.041	0.027	0.008	0.009	0.008	0.011
Bi_2O_3	0.037	0.063	0.060	0.033	0.055	0.032	0.045	0.056
SiO_2	0.016	0.034	0.051	0.072	0.055	0.044	0.025	0.041
H2O(calc)	0.614	0.636	0.570	0.607	0.530	0.570	0.594	0.633
F	2.218	2.155	2.300	2.218	2.433	2.388	2.314	2.219
O=F	0.934	0.907	0.968	0.934	1.024	1.005	0.974	0.934
subtotal	97.111	96.705	96.927	96.729	101.423	101.852	101.291	100.933
Total	**96.178**	**95.798**	**95.959**	**95.795**	**100.399**	**100.847**	**100.317**	**99.998**
apfu								
Ta	1.800	1.805	1.801	1.803	2.010	1.959	1.970	1.977
Nb	0.194	0.198	0.200	0.200	0.084	0.141	0.145	0.146
Ca	1.268	1.249	1.247	1.246	0.986	1.046	1.034	0.994
Na	0.408	0.400	0.420	0.398	0.328	0.360	0.321	0.352
Ti	0.014	0.009	0.007	0.009	0.030	0.001	0.002	0.001
Al	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.004	0.006	0.005	0.004	0.013	0.003	0.002	0.002
Mn	0.005	0.009	0.007	0.009	0.025	0.008	0.006	0.007
Sn	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Bi	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Si	0.001	0.003	0.005	0.007	0.005	0.004	0.002	0.004
OH	0.369	0.384	0.343	0.366	0.315	0.335	0.351	0.375
F	0.631	0.616	0.656	0.634	0.685	0.665	0.648	0.624

	L1-5-2-1	L1-5-4-1	L1-5-5-1	L1-5-6-1	L1-5-7-1	L1-5-9-1	L1-5-cu-1	L1-5-cu-2
oxide								
Ta_2O_5	81.335	56.676	57.423	58.451	58.555	74.990	74.673	75.012
Nb_2O_5	3.890	5.888	6.980	5.785	6.056	3.670	4.120	3.893
CaO	10.101	16.099	15.774	16.012	15.877	12.412	11.890	11.780
Na_2O	1.943	0.877	1.813	1.781	1.870	2.892	1.981	2.012
TiO_2	0.020	6.554	5.650	5.122	4.890	0.154	0.232	0.191
Al_2O_3	0.000	0.000	0.000	0.000	0.022	0.044	0.023	0.054
FeO	0.026	0.077	0.344	0.191	0.133	0.011	0.014	0.020
MnO	0.077	0.054	0.216	0.223	0.167	0.028	0.022	0.027
SnO_2	0.022	0.000	0.000	0.000	0.000	0.012	0.009	0.011
WO_3	0.000	0.000	0.000	0.000	0.000	0.022	0.000	0.000
UO_2	0.014	3.889	3.965	4.033	3.888	0.087	1.210	0.323
Bi_2O_3	0.033	3.998	2.776	2.566	2.335	0.015	0.018	0.022
SiO_2	0.052	0.023	0.022	0.054	0.121	0.098	0.067	0.036
H2O(calc)	0.512	0.666	0.669	0.649	0.542	0.334	0.351	0.262
F	2.454	2.320	2.356	2.334	2.554	2.792	2.723	2.882
O=F	1.033	0.977	0.992	0.983	1.075	1.176	1.147	1.213
subtotal	100.479	97.121	97.988	97.201	97.010	97.561	97.333	96.525
Total	**99.446**	**96.144**	**96.996**	**96.218**	**95.935**	**96.385**	**96.187**	**95.312**
apfu								
Ta	1.979	1.308	1.311	1.358	1.362	1.845	1.854	1.877
Nb	0.157	0.226	0.265	0.223	0.234	0.150	0.170	0.162
Ca	0.968	1.464	1.419	1.465	1.455	1.203	1.163	1.162
Na	0.337	0.144	0.295	0.295	0.310	0.507	0.351	0.359
Ti	0.001	0.418	0.357	0.329	0.315	0.010	0.016	0.013
Al	0.000	0.000	0.000	0.000	0.002	0.005	0.002	0.006
Fe	0.002	0.005	0.024	0.014	0.010	0.001	0.001	0.002
Mn	0.006	0.004	0.015	0.016	0.012	0.002	0.002	0.002
Sn	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
U	0.000	0.073	0.074	0.077	0.074	0.002	0.025	0.007
Bi	0.001	0.088	0.060	0.057	0.052	0.000	0.000	0.001
Si	0.005	0.002	0.002	0.005	0.010	0.009	0.006	0.003
OH	0.306	0.377	0.375	0.369	0.309	0.201	0.214	0.161
F	0.694	0.623	0.625	0.630	0.691	0.799	0.786	0.839

	L1-7-1	L1-7-2	L1-7-3	L1-7-4	L1-7-5	L1-7-6	L1-7-7	L1-7-8
oxide								
Ta_2O_5	81.778	73.760	74.226	75.324	74.556	74.598	75.455	74.393
Nb_2O_5	1.650	4.990	4.345	3.890	4.332	4.132	3.930	4.554
CaO	10.009	12.987	13.332	12.782	13.095	13.110	12.892	13.009
Na_2O	2.113	2.012	2.430	1.881	2.091	2.320	1.667	2.092
TiO_2	0.113	0.088	0.055	0.092	0.113	0.082	0.114	0.124
Al_2O_3	0.050	0.022	0.012	0.033	0.024	0.022	0.032	0.029
FeO	0.032	0.011	0.023	0.009	0.014	0.017	0.010	0.022
MnO	0.021	0.031	0.021	0.031	0.023	0.028	0.018	0.016
SnO_2	0.054	0.044	0.037	0.012	0.043	0.036	0.067	0.112
WO_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UO_2	0.177	0.099	0.078	0.033	0.092	0.082	0.101	0.071
Bi_2O_3	0.033	0.023	0.043	0.022	0.038	0.028	0.032	0.044
SiO_2	0.065	0.047	0.087	0.040	0.033	0.083	0.044	0.034
H2O(calc)	0.554	0.298	0.510	0.432	0.532	0.327	0.543	0.650
F	2.277	2.876	2.447	2.567	2.383	2.820	2.340	2.140
O=F	0.959	1.211	1.030	1.081	1.003	1.187	0.985	0.901
subtotal	98.926	97.288	97.646	97.148	97.369	97.685	97.245	97.290
Total	**97.967**	**96.077**	**96.616**	**96.067**	**96.366**	**96.497**	**96.259**	**96.389**
apfu								
Ta	2.042	1.810	1.812	1.863	1.829	1.828	1.862	1.822
Nb	0.068	0.204	0.176	0.160	0.177	0.168	0.161	0.185
Ca	0.984	1.255	1.282	1.246	1.266	1.266	1.254	1.255
Na	0.376	0.352	0.423	0.332	0.366	0.405	0.293	0.365
Ti	0.008	0.006	0.004	0.006	0.008	0.006	0.008	0.008
Al	0.005	0.002	0.001	0.004	0.003	0.002	0.003	0.003
Fe	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.002
Mn	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001
Sn	0.002	0.002	0.001	0.000	0.002	0.001	0.002	0.004
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.004	0.002	0.002	0.001	0.002	0.002	0.002	0.001
Bi	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Si	0.006	0.004	0.008	0.004	0.003	0.007	0.004	0.003
OH	0.339	0.179	0.305	0.262	0.320	0.196	0.328	0.390
F	0.661	0.821	0.695	0.738	0.680	0.804	0.672	0.610

	L1-7-9	L1-10-1	L1-10-2	L1-10-4	L1-10-8	L1-11-1	L1-11-2	L1-11-3
oxide								
Ta_2O_5	76.112	76.778	76.555	75.112	75.331	75.660	60.115	59.512
Nb_2O_5	3.243	3.003	3.563	4.090	4.230	3.983	5.760	6.094
CaO	12.772	11.891	11.712	11.556	11.334	12.556	15.441	16.003
Na_2O	2.119	1.991	2.121	2.233	2.578	1.891	2.001	1.781
TiO_2	0.073	0.023	0.041	0.133	0.123	0.151	5.004	4.674
Al_2O_3	0.019	0.020	0.031	0.012	0.092	0.033	0.041	0.014
FeO	0.009	0.013	0.015	0.020	0.043	0.043	0.099	0.077
MnO	0.033	0.022	0.016	0.023	0.062	0.047	0.132	0.141
SnO_2	0.082	0.010	0.033	0.088	0.011	0.100	0.012	0.000
WO_3	0.000	0.000	0.000	0.009	0.000	0.012	0.000	0.009
UO_2	0.044	0.022	0.017	0.123	0.054	0.254	3.544	3.677
Bi_2O_3	0.056	0.022	0.052	0.044	0.013	0.027	1.450	1.981
SiO_2	0.054	0.062	0.092	0.074	0.034	0.055	0.088	0.088
H2O(calc)	0.543	0.470	0.350	0.522	0.425	0.506	0.646	0.594
F	2.335	2.440	2.720	2.344	2.566	2.431	2.334	2.444
O=F	0.983	1.027	1.145	0.987	1.080	1.024	0.983	1.029
subtotal	97.494	96.767	97.318	96.383	96.896	97.749	96.667	97.089
Total	**96.511**	**95.739**	**96.172**	**95.396**	**95.816**	**96.726**	**95.684**	**96.060**
apfu								
Ta	1.881	1.925	1.904	1.876	1.871	1.860	1.399	1.383
Nb	0.133	0.125	0.147	0.170	0.175	0.163	0.223	0.235
Ca	1.243	1.174	1.148	1.137	1.109	1.216	1.415	1.466
Na	0.373	0.356	0.376	0.398	0.456	0.331	0.332	0.295
Ti	0.005	0.002	0.003	0.009	0.008	0.010	0.322	0.301
Al	0.002	0.002	0.003	0.001	0.010	0.004	0.004	0.001
Fe	0.001	0.001	0.001	0.002	0.003	0.003	0.007	0.006
Mn	0.003	0.002	0.001	0.002	0.005	0.004	0.010	0.010
Sn	0.003	0.000	0.001	0.003	0.000	0.004	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.001	0.000	0.000	0.003	0.001	0.005	0.067	0.070
Bi	0.001	0.001	0.001	0.001	0.000	0.001	0.032	0.044
Si	0.005	0.006	0.008	0.007	0.003	0.005	0.008	0.008
OH	0.329	0.289	0.213	0.319	0.259	0.305	0.368	0.339
F	0.671	0.711	0.787	0.681	0.741	0.695	0.631	0.661

	L1-11-6	L1-11-7	L1-12-1	L1-12-2	L1-12-4	L1-12-5	L1-12-cu-1	L1-12-cu-2
oxide								
Ta_2O_5	59.985	74.778	60.567	60.567	61.001	60.567	66.889	66.930
Nb_2O_5	6.110	5.009	5.345	5.456	5.556	5.834	3.009	2.998
CaO	15.093	10.980	14.894	15.119	14.890	14.334	14.554	14.894
Na_2O	2.440	2.336	1.990	2.092	2.540	2.338	1.660	1.412
TiO_2	4.434	0.089	5.009	4.456	3.993	4.520	0.121	0.091
Al_2O_3	0.033	0.120	0.020	0.009	0.028	0.030	0.014	0.022
FeO	0.071	0.092	0.050	0.042	0.051	0.033	0.041	0.021
MnO	0.088	0.130	0.110	0.078	0.056	0.075	0.049	0.023
SnO_2	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000
WO_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UO_2	3.448	0.232	4.556	4.045	4.009	3.893	6.998	7.223
Bi_2O_3	0.991	0.014	1.113	1.340	1.335	1.229	0.011	0.014
SiO_2	0.032	0.055	0.044	0.022	0.031	0.046	0.033	0.029
H2O(calc)	0.541	0.453	0.469	0.616	0.506	0.510	0.525	0.445
F	2.512	2.512	2.678	2.335	2.567	2.556	2.277	2.454
O=F	1.058	1.058	1.128	0.983	1.081	1.076	0.959	1.033
subtotal	95.778	96.809	96.845	96.177	96.563	95.965	96.181	96.556
Total	**94.720**	**95.752**	**95.717**	**95.194**	**95.482**	**94.889**	**95.222**	**95.522**
apfu								
Ta	1.412	1.854	1.421	1.432	1.444	1.434	1.700	1.697
Nb	0.239	0.206	0.208	0.214	0.219	0.230	0.127	0.126
Ca	1.400	1.073	1.376	1.409	1.389	1.337	1.457	1.488
Na	0.410	0.413	0.333	0.353	0.429	0.395	0.301	0.255
Ti	0.289	0.006	0.325	0.291	0.261	0.296	0.009	0.006
Al	0.003	0.013	0.002	0.001	0.003	0.003	0.002	0.002
Fe	0.005	0.007	0.004	0.003	0.004	0.002	0.003	0.002
Mn	0.006	0.010	0.008	0.006	0.004	0.006	0.004	0.002
Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.066	0.005	0.087	0.078	0.078	0.075	0.146	0.150
Bi	0.022	0.000	0.025	0.030	0.030	0.028	0.000	0.000
Si	0.003	0.005	0.004	0.002	0.003	0.004	0.003	0.003
OH	0.312	0.276	0.270	0.357	0.293	0.296	0.327	0.276
F	0.688	0.724	0.730	0.642	0.707	0.704	0.673	0.724

	L1-12-cu-3	L1-12-cu-4	L1-12-cu-5	L1-12-cu-6	L1-12-cu-7	L1-12-cu-8	L1-12-cu-9	L1-12-cu-10
oxide								
Ta_2O_5	67.133	66.513	67.100	66.114	74.423	75.384	75.677	75.232
Nb_2O_5	2.892	3.332	2.782	3.620	5.474	5.850	5.445	6.120
CaO	15.121	15.093	15.045	15.220	11.131	12.009	11.981	12.091
Na_2O	1.334	1.292	1.781	1.440	2.412	2.091	1.871	2.113
TiO_2	0.088	0.101	0.106	0.113	0.021	0.018	0.032	0.044
Al_2O_3	0.019	0.026	0.041	0.044	0.023	0.012	0.022	0.023
FeO	0.019	0.016	0.020	0.011	0.055	0.041	0.048	0.024
MnO	0.012	0.011	0.017	0.043	0.089	0.071	0.055	0.041
SnO_2	0.000	0.012	0.009	0.000	0.019	0.013	0.009	0.012
WO_3	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UO_2	7.092	6.652	6.700	7.030	0.323	0.343	0.092	0.089
Bi_2O_3	0.019	0.014	0.034	0.063	0.191	0.078	0.023	0.013
SiO_2	0.040	0.022	0.041	0.063	0.033	0.012	0.032	0.045
H2O(calc)	0.345	0.342	0.275	0.303	0.473	0.599	0.521	0.488
F	2.670	2.667	2.823	2.782	2.484	2.292	2.430	2.540
O=F	1.124	1.123	1.189	1.171	1.046	0.965	1.023	1.069
subtotal	96.797	96.093	96.774	96.846	97.151	98.813	98.238	98.875
Total	**95.673**	**94.970**	**95.585**	**95.675**	**96.105**	**97.848**	**97.215**	**97.806**
apfu								
Ta	1.699	1.688	1.695	1.662	1.839	1.823	1.844	1.812
Nb	0.122	0.141	0.117	0.151	0.225	0.235	0.221	0.245
Ca	1.508	1.509	1.498	1.507	1.084	1.144	1.150	1.148
Na	0.241	0.234	0.321	0.258	0.425	0.360	0.325	0.363
Ti	0.006	0.007	0.007	0.008	0.001	0.001	0.002	0.003
Al	0.002	0.003	0.004	0.005	0.002	0.001	0.002	0.002
Fe	0.001	0.001	0.002	0.001	0.004	0.003	0.004	0.002
Mn	0.001	0.001	0.001	0.003	0.007	0.005	0.004	0.003
Sn	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.147	0.138	0.139	0.145	0.007	0.007	0.002	0.002
Bi	0.000	0.000	0.001	0.002	0.004	0.002	0.001	0.000
Si	0.004	0.002	0.004	0.006	0.003	0.001	0.003	0.004
OH	0.214	0.213	0.170	0.187	0.286	0.355	0.312	0.288
F	0.786	0.787	0.829	0.813	0.714	0.644	0.688	0.712

	L1-15-1	L1-15-2	L1-15-3	L1-15-4	L1-15-5	L1-15-6	L1-16-1	L1-16-2
oxide								
Ta_2O_5	75.100	74.630	74.770	60.444	60.704	60.650	72.340	61.091
Nb_2O_5	6.444	5.999	5.667	6.545	6.340	6.540	7.776	5.223
CaO	12.672	12.434	12.782	15.656	15.334	15.410	11.556	16.090
Na_2O	2.332	2.440	1.778	1.671	1.981	1.844	2.328	2.223
TiO_2	0.024	0.017	0.020	4.094	4.412	4.334	0.028	5.556
Al_2O_3	0.018	0.032	0.019	0.023	0.043	0.023	0.012	0.044
FeO	0.014	0.033	0.021	0.025	0.040	0.064	0.069	0.041
MnO	0.022	0.041	0.018	0.034	0.034	0.054	0.065	0.044
SnO_2	0.014	0.021	0.016	0.000	0.000	0.000	0.009	0.000
WO_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UO_2	0.112	0.089	0.121	3.887	3.783	3.672	0.101	2.782
Bi_2O_3	0.033	0.025	0.023	0.762	0.623	0.654	0.054	0.345
SiO_2	0.022	0.043	0.048	0.044	0.035	0.041	0.084	0.024
H2O(calc)	0.556	0.499	0.503	0.550	0.612	0.381	0.587	0.552
F	2.442	2.523	2.488	2.500	2.383	2.872	2.312	2.567
O=F	1.028	1.062	1.048	1.053	1.003	1.209	0.973	1.081
subtotal	99.805	98.826	98.274	96.235	96.324	96.539	97.321	96.582
Total	**98.777**	**97.764**	**97.226**	**95.183**	**95.321**	**95.330**	**96.348**	**95.501**
apfu								
Ta	1.785	1.795	1.812	1.420	1.420	1.419	1.751	1.407
Nb	0.255	0.240	0.228	0.256	0.247	0.254	0.313	0.200
Ca	1.186	1.178	1.221	1.449	1.413	1.420	1.102	1.460
Na	0.395	0.418	0.307	0.280	0.330	0.308	0.402	0.365
Ti	0.002	0.001	0.001	0.266	0.286	0.280	0.002	0.354
Al	0.002	0.003	0.002	0.002	0.004	0.002	0.001	0.004
Fe	0.001	0.002	0.002	0.002	0.003	0.005	0.005	0.003
Mn	0.002	0.003	0.001	0.002	0.002	0.004	0.005	0.003
Sn	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.002	0.002	0.002	0.075	0.072	0.070	0.002	0.052
Bi	0.001	0.001	0.001	0.017	0.014	0.015	0.001	0.008
Si	0.002	0.004	0.004	0.004	0.003	0.004	0.007	0.002
OH	0.324	0.294	0.299	0.317	0.351	0.219	0.348	0.312
F	0.675	0.706	0.701	0.683	0.648	0.781	0.651	0.687

	L1-16-3	L1-16-4	L1-16-8	L1-16-10	L1-18-1	L1-18-2	L1-18-3	L1-18-4
oxide								
Ta_2O_5	60.223	60.093	59.995	71.877	60.455	59.566	60.156	60.780
Nb_2O_5	6.094	6.220	6.560	8.220	5.985	6.896	6.101	7.222
CaO	15.523	15.093	15.330	11.760	15.750	15.340	15.412	15.788
Na_2O	1.981	2.043	1.230	2.111	1.998	2.146	2.241	1.771
TiO_2	5.044	5.323	6.670	0.026	4.874	5.094	5.222	4.334
Al_2O_3	0.056	0.048	0.034	0.000	0.021	0.019	0.032	0.022
FeO	0.038	0.040	0.009	0.044	0.023	0.036	0.029	0.011
MnO	0.048	0.074	0.013	0.056	0.044	0.026	0.032	0.034
SnO_2	0.000	0.000	0.000	0.043	0.000	0.000	0.000	0.000
WO_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UO_2	3.423	3.411	2.892	0.099	3.331	3.298	3.229	3.555
Bi_2O_3	0.451	0.389	0.050	0.043	0.213	0.222	0.198	0.091
SiO_2	0.028	0.031	0.089	0.033	0.099	0.083	0.123	0.092
H2O(calc)	0.587	0.535	0.626	0.627	0.643	0.664	0.595	0.658
F	2.451	2.567	2.445	2.232	2.334	2.310	2.450	2.334
O=F	1.032	1.081	1.029	0.940	0.983	0.973	1.032	0.983
subtotal	95.947	95.867	95.943	97.171	95.770	95.700	95.820	96.692
Total	**94.915**	**94.786**	**94.913**	**96.231**	**94.787**	**94.727**	**94.788**	**95.709**
apfu								
Ta	1.403	1.398	1.370	1.738	1.409	1.380	1.395	1.404
Nb	0.236	0.241	0.249	0.331	0.232	0.266	0.235	0.277
Ca	1.424	1.384	1.379	1.121	1.446	1.401	1.409	1.437
Na	0.329	0.339	0.200	0.364	0.332	0.355	0.371	0.292
Ti	0.325	0.343	0.421	0.002	0.314	0.327	0.335	0.277
Al	0.006	0.005	0.003	0.000	0.002	0.002	0.003	0.002
Fe	0.003	0.003	0.001	0.003	0.002	0.003	0.002	0.001
Mn	0.003	0.005	0.001	0.004	0.003	0.002	0.002	0.002
Sn	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.065	0.065	0.054	0.002	0.064	0.063	0.061	0.067
Bi	0.010	0.009	0.001	0.001	0.005	0.005	0.004	0.002
Si	0.002	0.003	0.007	0.003	0.008	0.007	0.010	0.008
OH	0.335	0.305	0.350	0.372	0.367	0.377	0.339	0.373
F	0.664	0.695	0.649	0.628	0.632	0.623	0.661	0.627

	L1-18-5	L1-18-6	L2-2-7	L2-2-8	L2-2-9	L2-5-2
oxide						
Ta_2O_5	60.445	60.683	71.345	71.650	71.500	72.115
Nb_2O_5	6.980	7.154	8.887	8.450	8.650	7.870
CaO	15.900	15.498	10.912	11.009	11.102	10.671
Na_2O	1.678	1.712	2.330	2.144	2.167	2.445
TiO_2	4.123	4.093	0.043	0.031	0.026	0.033
Al_2O_3	0.029	0.043	0.000	0.009	0.022	0.044
FeO	0.045	0.023	0.022	0.018	0.017	0.020
MnO	0.048	0.038	0.026	0.020	0.019	0.017
SnO_2	0.000	0.000	0.012	0.023	0.025	0.034
WO_3	0.000	0.000	0.000	0.000	0.000	0.000
UO_2	3.873	3.770	0.225	0.312	0.277	0.133
Bi_2O_3	0.123	0.143	0.544	0.484	0.566	0.343
SiO_2	0.234	0.191	0.067	0.114	0.191	0.332
H2O(calc)	0.631	0.491	0.668	0.570	0.627	0.668
F	2.376	2.662	2.145	2.337	2.240	2.130
O=F	1.000	1.121	0.903	0.984	0.943	0.897
subtotal	96.485	96.501	97.226	97.171	97.429	96.855
Total	**95.485**	**95.380**	**96.323**	**96.187**	**96.485**	**95.959**
apfu						
Ta	1.402	1.411	1.726	1.740	1.726	1.752
Nb	0.269	0.277	0.357	0.341	0.347	0.318
Ca	1.453	1.420	1.040	1.053	1.056	1.021
Na	0.277	0.284	0.402	0.371	0.373	0.423
Ti	0.265	0.263	0.003	0.002	0.002	0.002
Al	0.003	0.004	0.000	0.001	0.002	0.005
Fe	0.003	0.002	0.002	0.001	0.001	0.001
Mn	0.003	0.003	0.002	0.002	0.001	0.001
Sn	0.000	0.000	0.000	0.001	0.001	0.001
W	0.000	0.000	0.000	0.000	0.000	0.000
U	0.073	0.072	0.004	0.006	0.005	0.003
Bi	0.003	0.003	0.012	0.011	0.013	0.008
Si	0.020	0.016	0.006	0.010	0.017	0.030
OH	0.359	0.280	0.396	0.339	0.371	0.398
F	0.641	0.720	0.604	0.660	0.629	0.602

	L2-5-5	L2-5-6	L2-5-7	L2-5-8	L2-5-9
oxide					
Ta_2O_5	71.891	71.873	71.833	72.982	72.872
Nb_2O_5	7.450	7.530	7.456	6.560	6.665
CaO	11.091	10.891	10.560	11.455	11.982
Na_2O	2.312	2.278	2.293	1.810	1.934
TiO_2	0.212	0.222	0.189	0.221	0.181
Al_2O_3	0.012	0.031	0.035	0.000	0.022
FeO	0.082	0.044	0.050	0.033	0.041
MnO	0.023	0.027	0.023	0.018	0.043
SnO_2	0.043	0.038	0.056	0.011	0.018
WO_3	0.000	0.000	0.000	0.000	0.000
UO_2	0.094	0.105	0.112	0.119	0.213
Bi_2O_3	0.292	0.344	0.309	0.292	0.229
SiO_2	0.119	0.081	0.055	0.045	0.078
H2O(calc)	0.675	0.640	0.698	0.542	0.519
F	2.092	2.156	2.009	2.345	2.434
O=F	0.881	0.908	0.846	0.987	1.025
subtotal	96.388	96.260	95.678	96.433	97.231
Total	**95.507**	**95.352**	**94.832**	**95.446**	**96.206**
apfu					
Ta	1.758	1.763	1.775	1.799	1.776
Nb	0.303	0.307	0.306	0.269	0.270
Ca	1.069	1.052	1.028	1.113	1.151
Na	0.403	0.398	0.404	0.318	0.336
Ti	0.014	0.015	0.013	0.015	0.012
Al	0.001	0.003	0.004	0.000	0.002
Fe	0.006	0.003	0.004	0.003	0.003
Mn	0.002	0.002	0.002	0.001	0.003
Sn	0.002	0.001	0.002	0.000	0.001
W	0.000	0.000	0.000	0.000	0.000
U	0.002	0.002	0.002	0.002	0.004
Bi	0.007	0.008	0.007	0.007	0.005
Si	0.011	0.007	0.005	0.004	0.007
OH	0.405	0.385	0.423	0.328	0.310
F	0.595	0.615	0.577	0.672	0.690

Microprobe analyses for all apatite samples

Standards for EMP analyses for **Apatite** Acceleration potential: 15-20 kV Beam current: 15-22 nA Count times: 45 seconds per spot	
Clinopyroxene, “Cpx-26-ano”	Si
Clinopyroxene, “Cpx-26-ano”	Al
Clinopyroxene, “Cpx-26-ano”	Fe
Clinopyroxene, “Cpx-26-ano”	Mg
Fluor-apatite, Cerro de Mercado Mexico	Ca
Lithiophilite Emmons, ME	Mn
Fluor-apatite Cerro de Mercado Mexico	P
Fluor-apatite, Cerro de Mercado Mexico	F
Other MAN standards used: Al_2O_3, synthetic Hematite, Elba MgO, synthetic PbO, synthetic V_2O_5, synthetic ZnO, synthetic ZrO_2, synthetic	

Apatite analyses were calculated based on 12 oxygen.

Apatite								
	L3-7	1.1B-1	U10A-7	1.4-1	1.4-2	1.4-3	1.5-1	1.5-2
oxide	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
SiO_2	0.044	0.044	0.094	0.011	0.000	0.000	0.000	0.022
Al_2O_3	0.000	0.000	0.000	0.098	0.009	0.044	0.011	0.014
FeO	0.022	0.000	0.000	1.090	0.890	0.023	0.772	0.112
MgO	0.000	0.000	0.000	0.014	0.011	0.033	0.000	0.000
CaO	55.655	55.670	55.445	50.556	50.422	54.333	51.621	53.232
MnO	0.018	0.023	0.000	3.780	4.111	1.020	3.654	2.092
P_2O_5	42.366	42.500	42.444	41.344	41.454	41.611	41.243	41.355
F	2.982	2.870	3.110	3.210	3.122	3.092	3.210	3.092
H_20 calc.	0.534	0.591	0.474	0.382	0.424	0.454	0.386	0.444
subtotal	101.621	101.698	101.567	100.485	100.443	100.610	100.897	100.363
F=O	1.256	1.208	1.309	1.352	1.315	1.302	1.352	1.302
Total	100.366	100.490	100.257	99.133	99.128	99.308	99.546	99.061
apfu								
Si	0.004	0.004	0.008	0.001	0.000	0.000	0.000	0.002
Al	0.000	0.000	0.000	0.010	0.001	0.004	0.001	0.001
Fe	0.002	0.000	0.000	0.078	0.063	0.002	0.055	0.008
Mg	0.000	0.000	0.000	0.002	0.001	0.004	0.000	0.000
Ca	4.972	4.964	4.953	4.622	4.609	4.924	4.708	4.850
Mn	0.001	0.002	0.000	0.273	0.297	0.073	0.263	0.151
P	2.991	2.994	2.996	2.987	2.994	2.980	2.972	2.977
F	0.786	0.755	0.820	0.866	0.842	0.827	0.864	0.832
OH	0.297	0.328	0.263	0.217	0.241	0.256	0.219	0.252
x-site	4.978	4.969	4.961	4.986	4.972	5.007	5.027	5.012
y-site	2.991	2.994	2.996	2.987	2.994	2.980	2.972	2.977
z-site	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083

Apatite								
	1.5-3	1.7-1	1.7-2	1.7-3	CZ1A-2-1	CZ1A-2-2	CZ1A-2-3	CZ1A-1
oxide	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
SiO_2	0.014	0.000	0.000	0.022	0.011	0.009	0.000	0.008
Al_2O_3	0.000	0.009	0.000	0.143	0.000	0.000	0.000	0.022
FeO	0.022	0.034	0.031	0.455	0.007	0.000	0.009	0.008
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	54.334	53.893	54.009	53.773	55.320	55.324	55.431	55.383
MnO	1.121	1.333	1.091	1.012	0.021	0.022	0.033	0.042
P_2O_5	42.091	42.220	42.188	41.789	42.144	42.092	41.789	41.991
F	3.112	3.093	3.288	3.184	3.455	3.493	3.383	3.423
H_20 calc.	0.458	0.467	0.372	0.415	0.298	0.279	0.324	0.312
subtotal	101.152	101.049	100.979	100.793	101.256	101.219	100.969	101.189
F=O	1.310	1.302	1.384	1.341	1.455	1.471	1.424	1.441
Total	99.842	99.746	99.595	99.452	99.801	99.748	99.545	99.748
apfu								
Si	0.001	0.000	0.000	0.002	0.001	0.001	0.000	0.001
Al	0.000	0.001	0.000	0.014	0.000	0.000	0.000	0.002
Fe	0.002	0.002	0.002	0.032	0.000	0.000	0.001	0.001
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	4.891	4.852	4.867	4.863	4.972	4.976	5.004	4.984
Mn	0.080	0.095	0.078	0.072	0.001	0.002	0.002	0.003
P	2.994	3.003	3.004	2.986	2.993	2.992	2.981	2.986
F	0.827	0.822	0.875	0.850	0.917	0.927	0.901	0.909
OH	0.257	0.261	0.209	0.233	0.167	0.156	0.182	0.175
x-site	4.973	4.950	4.947	4.984	4.975	4.978	5.007	4.991
y-site	2.994	3.003	3.004	2.986	2.993	2.992	2.981	2.986
z-site	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.084

Apatite								
	CZ1A-2	CZ1A-3	CZ1B-1	CZ1B-2	CZ1B-3	CZ3B-1	CZ3B-2	CZ3B-3
oxide	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
SiO_2	0.000	0.009	0.000	0.033	0.021	0.008	0.000	0.009
Al_2O_3	0.019	0.008	0.000	0.011	0.000	0.022	0.019	0.008
FeO	0.009	0.011	0.000	0.012	0.014	0.008	0.000	0.011
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	55.412	55.378	55.444	55.383	55.400	55.412	55.389	55.404
MnO	0.036	0.044	0.046	0.050	0.054	0.015	0.028	0.025
P_2O_5	42.012	42.089	42.022	41.981	42.009	42.022	42.092	41.988
F	3.378	3.410	3.289	3.229	3.341	3.334	3.265	3.310
H_20 calc.	0.333	0.320	0.375	0.403	0.350	0.354	0.388	0.364
subtotal	101.199	101.269	101.176	101.102	101.189	101.175	101.181	101.119
F=O	1.422	1.436	1.385	1.360	1.407	1.404	1.375	1.394
Total	99.776	99.833	99.791	99.742	99.783	99.771	99.806	99.725
apfu								
Si	0.000	0.001	0.000	0.003	0.002	0.001	0.000	0.001
Al	0.002	0.001	0.000	0.001	0.000	0.002	0.002	0.001
Fe	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	4.985	4.978	4.988	4.984	4.984	4.985	4.979	4.987
Mn	0.003	0.003	0.003	0.004	0.004	0.001	0.002	0.002
P	2.987	2.990	2.987	2.985	2.986	2.987	2.990	2.986
F	0.897	0.905	0.873	0.858	0.887	0.885	0.866	0.879
OH	0.186	0.179	0.210	0.226	0.196	0.198	0.217	0.204
x-site	4.990	4.983	4.991	4.992	4.991	4.989	4.983	4.991
y-site	2.987	2.990	2.987	2.985	2.986	2.987	2.990	2.986
z-site	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083

Apatite from within Feldspars								
	CZ5-4	CZ1A6-1-1	CZ1A6-1-2	CZ1A6-1-3	CZ7-4	CZ8-1	CZ8-2	CZ8-3
oxide	wt %	wt %	wt %	wt %	wt %	wt %	wt %	wt %
SiO_2	0.112	0.011	0.009	0.009	0.022	0.022	0.019	0.011
Al_2O_3	0.000	0.022	0.019	0.008	0.000	0.009	0.000	0.000
FeO	0.009	0.008	0.009	0.011	0.009	0.000	0.000	0.008
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CaO	55.344	55.333	55.378	55.411	55.332	55.405	55.415	55.388
MnO	0.016	0.037	0.036	0.033	0.011	0.024	0.022	0.028
P_2O_5	42.011	42.004	42.005	42.111	42.433	42.008	41.981	42.011
F	3.177	3.378	3.442	3.378	3.222	3.292	3.228	3.315
H_20 calc.	0.429	0.332	0.302	0.335	0.417	0.373	0.403	0.362
subtotal	101.098	101.125	101.200	101.296	101.446	101.133	101.068	101.123
F=O	1.338	1.422	1.449	1.422	1.357	1.386	1.359	1.396
Total	99.761	99.702	99.751	99.874	100.089	99.747	99.709	99.727
apfu								
Si	0.009	0.001	0.001	0.001	0.002	0.002	0.002	0.001
Al	0.000	0.002	0.002	0.001	0.000	0.001	0.000	0.000
Fe	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.001
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	4.976	4.981	4.983	4.978	4.952	4.985	4.988	4.985
Mn	0.001	0.003	0.003	0.002	0.001	0.002	0.002	0.002
P	2.985	2.988	2.987	2.990	3.001	2.987	2.986	2.988
F	0.843	0.897	0.914	0.896	0.851	0.874	0.858	0.881
OH	0.240	0.186	0.169	0.188	0.232	0.209	0.226	0.203
x-site	4.987	4.987	4.989	4.983	4.955	4.989	4.991	4.988
y-site	2.985	2.988	2.987	2.990	3.001	2.987	2.986	2.988
z-site	1.083	1.083	1.083	1.083	1.083	1.083	1.083	1.083

Apatite						
	CZ8-1	CZ8-2	CZ8-3	CZ8-2	CZ8-3	CZ8-4
oxide	wt %	wt %	wt %	wt %	wt %	wt %
SiO_2	0.022	0.019	0.011	0.019	0.011	0.101
Al_2O_3	0.009	0.000	0.000	0.000	0.000	0.009
FeO	0.000	0.000	0.008	0.000	0.008	0.005
MgO	0.000	0.000	0.000	0.000	0.000	0.000
CaO	55.405	55.415	55.388	55.415	55.388	55.455
MnO	0.024	0.022	0.028	0.022	0.028	0.000
P_2O_5	42.008	41.981	42.011	41.981	42.011	42.543
F	3.292	3.228	3.315	3.228	3.315	3.009
H_20 calc.	0.373	0.403	0.362	0.403	0.362	0.525
subtotal	101.133	101.068	101.123	101.068	101.123	101.647
F=O	1.386	1.359	1.396	1.359	1.396	1.267
Total	99.747	99.709	99.727	99.709	99.727	100.380
apfu						
Si	0.002	0.002	0.001	0.002	0.001	0.008
Al	0.001	0.000	0.000	0.000	0.000	0.001
Fe	0.000	0.000	0.001	0.000	0.001	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.000
Ca	4.985	4.988	4.985	4.988	4.985	4.945
Mn	0.002	0.002	0.002	0.002	0.002	0.000
P	2.987	2.986	2.988	2.986	2.988	2.998
F	0.874	0.858	0.881	0.858	0.881	0.792
OH	0.209	0.226	0.203	0.226	0.203	0.291
x-site	4.989	4.991	4.988	4.991	4.988	4.955
y-site	2.987	2.986	2.988	2.986	2.988	2.998
z-site	1.083	1.083	1.083	1.083	1.083	1.083

Microprobe data for all zircon samples.

Standards for EMP analyses for **Zircon** Acceleration potential: 15-20 kV Beam current: 15-22 nA Count times: 45 seconds per spot	
ZrO_2, synthetic	Zr
Clinopyroxene, “Cpx-26-ano”	Si
HfO_2, synthetic	Hf
Samarskite, Afghan	U
Hematite, Elba, Italy	Fe
Clinopyroxene, “Cpx-26-ano”	Ca
Clinopyroxene, “Cpx-26-ano”	Al
Rhodonite, Broken Hill	Mn
Rutile, synthetic	Ti
ThO_2, synthetic	Th
Other MAN standards used: Al_2O_3, synthetic Hematite, Elba MgO, synthetic PbO, synthetic V_2O_5, synthetic ZnO, synthetic ZrO_2, synthetic	

All zircon analyses were calculated based on 4 oxygen

	L3-1/2-1-core	L3-1/2-1-rim	L3-1/2-6-1core	L3-1/2-6-1rim	L3-1/2-6-2 cpre	L3-1/2-6-2 rim
oxide						
ZrO_2	59.655	58.874	59.005	58.75	58.887	58.445
SiO_2	31.555	31.091	31.103	31.009	31.033	30.873
HfO_2	5.778	6.76	5.56	6.3	5.233	6.1
UO_2	0.123	0.045	0.055	0.023	0.045	0.013
FeO	0.289	0.213	0.55	0.23	0.43	0.543
CaO	1.23	1.091	0.993	1.125	0.077	0.095
Al_2O_3	0.022	0.043	0.043	0.028	0	0.054
MnO	0.121	0.346	0.234	0.155	0.093	0.223
TiO_2	0.22	0.114	0.095	0.056	0.033	0.028
ThO_2	0.114	0.212	0.093	0.123	0.144	0.134
Total	**99.107**	**98.789**	**97.731**	**97.799**	**95.975**	**96.508**
apfu						
Zr	0.918	0.915	0.921	0.919	0.933	0.925
Si	0.996	0.991	0.996	0.995	1.008	1.003
Hf	0.052	0.062	0.051	0.058	0.049	0.057
U	0.001	0.000	0.000	0.000	0.000	0.000
Fe	0.008	0.006	0.015	0.006	0.012	0.015
Ca	0.042	0.037	0.034	0.039	0.003	0.003
Al	0.000	0.001	0.001	0.001	0.000	0.001
Mn	0.003	0.009	0.006	0.004	0.003	0.006
Ti	0.005	0.003	0.002	0.001	0.001	0.001
Th	0.001	0.002	0.001	0.001	0.001	0.001
x-site	1.030	1.034	1.030	1.029	1.000	1.008
y-site	0.996	0.992	0.997	0.996	1.008	1.004

	L3-1/2-9-1 core	L3-1/2-9-1 rim	L3-1/2-9-2 core	L3-1/2-9-2rim	L3-1/2-9-3 core	L3-1/2-9-3 rim
oxide						
ZrO_2	59.22	58.766	60.111	59.855	59.788	59.55
SiO_2	31.113	30.883	31.891	31.678	31.555	31.235
HfO_2	5.455	5.984	5.277	5.544	5.76	5.98
UO_2	0.05	0.019	0.03	0.022	0.045	0.032
FeO	0.345	0.243	0.343	0.365	0.445	0.423
CaO	1.221	1.091	0.233	0.232	0.777	0.803
Al_2O_3	0.034	0.015	0.043	0.033	0.019	0.043
MnO	0.254	0.233	0.189	0.123	0.093	0.033
TiO_2	0.044	0.034	0.022	0.025	0.032	0.026
ThO_2	0.093	0.087	0.093	0.089	0.112	0.092
Total	**97.829**	**97.355**	**98.232**	**97.966**	**98.626**	**98.217**
apfu						
Zr	0.923	0.923	0.928	0.929	0.924	0.926
Si	0.995	0.995	1.010	1.008	1.001	0.997
Hf	0.050	0.055	0.048	0.050	0.052	0.054
U	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.009	0.007	0.009	0.010	0.012	0.011
Ca	0.042	0.038	0.008	0.008	0.026	0.027
Al	0.001	0.000	0.001	0.001	0.000	0.001
Mn	0.007	0.006	0.005	0.003	0.002	0.001
Ti	0.001	0.001	0.001	0.001	0.001	0.001
Th	0.001	0.001	0.001	0.001	0.001	0.001
x-site	1.033	1.030	1.000	1.001	1.019	1.022
y-site	0.996	0.995	1.011	1.009	1.001	0.997

	L3-1/2-9-5 core	L3-1/2-9-5 rim	L3-1/2-9-6-core	L3-1/2-9-6-rim	L3-1/2-9-7 core	L3-1/2-9-7 rim
oxide						
ZrO_2	60.21	59.45	60.034	58.095	60.2	58.21
SiO_2	31.6	30.873	31.655	30.734	31.454	30.783
HfO_2	5.566	6.554	5.366	6.444	5.277	6.223
UO_2	0.013	0.022	0.113	0.063	0.143	0.092
FeO	0.023	0.021	0.254	0.133	0.232	0.191
CaO	0.094	0.088	0.366	0.433	0.277	0.32
Al_2O_3	0.011	0.023	0.009	0.013	0.011	0.019
MnO	0.011	0.018	0.011	0.009	0.055	0.034
TiO_2	0.015	0.019	0.013	0.022	0.033	0.018
ThO_2	0.065	0.045	0.223	0.312	0.223	0.282
Total	**97.608**	**97.113**	**98.044**	**96.258**	**97.905**	**96.172**
apfu						
Zr	0.937	0.937	0.931	0.924	0.936	0.926
Si	1.009	0.998	1.007	1.003	1.003	1.004
Hf	0.051	0.060	0.049	0.060	0.048	0.058
U	0.000	0.000	0.001	0.000	0.001	0.001
Fe	0.001	0.001	0.007	0.004	0.006	0.005
Ca	0.003	0.003	0.012	0.015	0.009	0.011
Al	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.001	0.001
Ti	0.000	0.000	0.000	0.001	0.001	0.000
Th	0.000	0.000	0.002	0.002	0.002	0.002
x-site	0.993	1.003	1.002	1.006	1.005	1.004
y-site	1.009	0.999	1.007	1.003	1.004	1.004

	L3-1/2-10-1 core	L3-1/2-10-1 rim	L3-1/2-10-2 core	L3-1/2-10-2 rim	L3-1/2-10-3 core	L3-1/2-10-3 rim
oxide						
ZrO_2	59.875	59.333	60.111	59.45	60.022	59.777
SiO_2	31.555	31.091	31.8	31.223	31.671	31.224
HfO_2	5.333	5.92	5.223	5.933	5.383	5.887
UO_2	0.098	0.077	0.1	0.076	0.11	0.089
FeO	0.21	0.181	0.244	0.312	0.211	0.191
CaO	0.311	0.282	0.044	0.034	0.433	0.413
Al_2O_3	0.044	0.034	0.09	0.073	0.022	0.009
MnO	0.022	0.028	0.022	0.029	0.033	0.028
TiO_2	0.02	0.021	0.017	0.022	0.016	0.019
ThO_2	0.121	0.109	0.223	0.243	0.222	0.322
Total	**97.589**	**97.076**	**97.874**	**97.395**	**98.123**	**97.959**
apfu						
Zr	0.932	0.933	0.932	0.932	0.930	0.933
Si	1.008	1.002	1.011	1.004	1.007	1.000
Hf	0.049	0.054	0.047	0.054	0.049	0.054
U	0.001	0.001	0.001	0.001	0.001	0.001
Fe	0.006	0.005	0.006	0.008	0.006	0.005
Ca	0.011	0.010	0.001	0.001	0.015	0.014
Al	0.001	0.001	0.002	0.001	0.000	0.000
Mn	0.001	0.001	0.001	0.001	0.001	0.001
Ti	0.000	0.001	0.000	0.001	0.000	0.000
Th	0.001	0.001	0.002	0.002	0.002	0.002
x-site	1.000	1.004	0.991	0.999	1.003	1.010
y-site	1.008	1.003	1.013	1.005	1.007	1.000

	L3-1/2-10-4 core	L3-1/2-10-4 rim	L3-1/2-10-5 core	L3-1/2-10-5 rim	L3-1/2-10-6 core	L3-1/2-10-6 core
oxide						
ZrO_2	60.223	59.445	59.787	59.211	59.834	59.544
SiO_2	31.873	30.783	31.334	30.54	31.223	30.893
HfO_2	5.022	5.995	5.677	6.21	5.585	5.923
UO_2	0.022	0.009	0.021	0.018	0.111	0.076
FeO	0.034	0.032	0.023	0.031	0.21	0.189
CaO	0.073	0.055	0.043	0.045	0.292	0.312
Al_2O_3	0.012	0.018	0	0.012	0.022	0.019
MnO	0.017	0.015	0.011	0.023	0.033	0.043
TiO_2	0.009	0.032	0.024	0.023	0.012	0.022
ThO_2	0.034	0.032	0.026	0.033	0.255	0.223
Total	**97.319**	**96.416**	**96.946**	**96.146**	**97.577**	**97.244**
apfu						
Zr	0.936	0.941	0.938	0.942	0.936	0.937
Si	1.016	1.000	1.008	0.997	1.001	0.997
Hf	0.046	0.056	0.052	0.058	0.051	0.055
U	0.000	0.000	0.000	0.000	0.001	0.001
Fe	0.001	0.001	0.001	0.001	0.006	0.005
Ca	0.002	0.002	0.001	0.002	0.010	0.011
Al	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.000	0.000	0.000	0.001	0.001	0.001
Ti	0.000	0.001	0.001	0.001	0.000	0.001
Th	0.000	0.000	0.000	0.000	0.002	0.002
x-site	0.986	1.001	0.993	1.004	1.006	1.011
y-site	1.016	1.000	1.008	0.997	1.002	0.997

	L3-1/2-11-1 core	L3-1/2-11-1 rim	L3-1/2-11-2 core	L3-1/2-11-2 rim	L3-1/2-11-4 core	L3-1/2-11-4 rim
oxide						
ZrO_2	60.222	60.004	60.1	59.984	59.984	59.12
SiO_2	31.9	31.78	31.888	31.81	31.761	30.999
HfO_2	4.844	4.998	4.784	5.092	5.092	6.093
UO_2	0.144	0.109	0.011	0.009	0.009	0.013
FeO	0.256	0.223	0.022	0.024	0.024	0.019
CaO	0.223	0.245	0.034	0.033	0.033	0.023
Al_2O_3	0.033	0.029	0	0.013	0.013	0.032
MnO	0.05	0.045	0.017	0.013	0.013	0.022
TiO_2	0.014	0.023	0.018	0.011	0.011	0.024
ThO_2	0.323	0.289	0.028	0.03	0.03	0.023
Total	**98.009**	**97.745**	**96.902**	**97.019**	**96.97**	**96.368**
apfu						
Zr	0.932	0.931	0.936	0.935	0.936	0.935
Si	1.012	1.011	1.019	1.017	1.016	1.006
Hf	0.044	0.045	0.044	0.046	0.046	0.056
U	0.001	0.001	0.000	0.000	0.000	0.000
Fe	0.007	0.006	0.001	0.001	0.001	0.001
Ca	0.008	0.008	0.001	0.001	0.001	0.001
Al	0.001	0.001	0.000	0.000	0.000	0.001
Mn	0.001	0.001	0.000	0.000	0.000	0.001
Ti	0.000	0.001	0.000	0.000	0.000	0.001
Th	0.002	0.002	0.000	0.000	0.000	0.000
x-site	0.995	0.995	0.983	0.984	0.985	0.994
y-site	1.013	1.012	1.019	1.017	1.016	1.006

	L3-1/2-11-5-core	L3-1/2-11-5-rim	L3-1/2-13-1 core	L3-1/2-13-1 rim	L3-1/2-13-2 core	L3-1/2-13-2rim
oxide						
ZrO_2	59.933	59.044	59.956	59.65	59.845	59.555
SiO_2	31.688	31.111	31.588	31.444	31.566	31.312
HfO_2	5.233	6.167	5.455	5.76	5.499	5.785
UO_2	0.34	0.025	0.056	0.033	0.12	0.078
FeO	0.073	0.055	0.345	0.282	0.133	0.154
CaO	0.212	0.191	0.445	0.243	0.144	0.092
Al_2O_3	0.022	0.024	0.022	0.012	0.022	0.018
MnO	0.034	0.033	0.112	0.082	0.033	0.025
TiO_2	0.014	0.02	0.033	0.028	0.02	0.023
ThO_2	0.225	0.202	0.155	0.101	0.212	0.223
Total	**97.774**	**96.872**	**98.167**	**97.635**	**97.594**	**97.265**
apfu						
Zr	0.932	0.930	0.930	0.930	0.933	0.933
Si	1.010	1.005	1.004	1.006	1.009	1.006
Hf	0.048	0.057	0.050	0.053	0.050	0.053
U	0.002	0.000	0.000	0.000	0.001	0.001
Fe	0.002	0.001	0.009	0.008	0.004	0.004
Ca	0.007	0.007	0.015	0.008	0.005	0.003
Al	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.001	0.001	0.003	0.002	0.001	0.001
Ti	0.000	0.000	0.001	0.001	0.000	0.001
Th	0.002	0.001	0.001	0.001	0.002	0.002
x-site	0.994	0.998	1.009	1.003	0.995	0.997
y-site	1.011	1.006	1.005	1.006	1.009	1.007

	L3-1/2-13-3 core	L3-1/2-13-3 rim	L3-1/2-13-4 core	L3-1/2-13-4 rim	L3-1/2-15-1 core	L3-1/2-15-1 rim
oxide						
ZrO_2	59.945	59.488	60.566	60.222	60.454	59.955
SiO_2	31.655	31.21	31.871	31.444	31.7	31.344
HfO_2	5.388	5.956	3.873	4.112	4.112	4.894
UO_2	0.045	0.032	0.044	0.023	0.112	0.091
FeO	0.133	0.101	0.102	0.089	0.322	0.244
CaO	0.121	0.091	0.2	0.155	0.223	0.243
Al_2O_3	0	0.011	0.031	0.027	0	0.014
MnO	0.025	0.02	0.022	0.016	0.055	0.033
TiO_2	0.011	0.023	0.009	0.011	0.033	0.034
ThO_2	0.122	0.091	0.113	0.089	0.212	0.145
Total	**97.445**	**97.023**	**96.831**	**96.188**	**97.223**	**96.997**
apfu						
Zr	0.934	0.935	0.941	0.945	0.940	0.938
Si	1.011	1.006	1.016	1.012	1.011	1.006
Hf	0.049	0.055	0.035	0.038	0.037	0.045
U	0.000	0.000	0.000	0.000	0.001	0.001
Fe	0.004	0.003	0.003	0.002	0.009	0.007
Ca	0.004	0.003	0.007	0.005	0.008	0.008
Al	0.000	0.000	0.001	0.001	0.000	0.000
Mn	0.001	0.001	0.001	0.000	0.001	0.001
Ti	0.000	0.001	0.000	0.000	0.001	0.001
Th	0.001	0.001	0.001	0.001	0.002	0.001
x-site	0.993	0.997	0.988	0.992	0.998	1.001
y-site	1.011	1.006	1.017	1.012	1.011	1.006

Microprobe analyses for all montebrasite-amblygonite samples

Standards for EMP analyses for **Montebrasite - Amblygonite** Acceleration potential: 15-20 kV Beam current: 15-22 nA Count times: 45 seconds per spot	
Fluorapatite, Cerro de Mercado Mexico	Ca
Lithiophilite, Emmons, ME	Mn
Triphylite, Palermo #1, ME	Fe
MgO, synthetic	Mg
Amblygonite, Tanco Pegmatite Canada	Al
Amblygonite, Tanco Pegmatite Canada	P
Clinopyroxene, “Cpx-26-ano”	Si
Rutile, synthetic	Ti
Adularia, Fibbia Switzerland	K
Elbaite, Alba, Italy	Na
Amblygonite, Tanco Pegmatite Canada	F
$SrSO_4$, synthetic	Sr
$BaSO_4$, synthetic	Ba
Other MAN standards used: Al_2O_3, synthetic Hematite, Elba MgO, synthetic PbO, synthetic V_2O_5, synthetic ZnO, synthetic ZrO_2, synthetic	

Montebrasite-Amblygonite analyses were calculated based on 5 oxygen.

montebrasite-amblygonite								
	M1-1	M1-3	M3-1	M3-2	M3-3	M4-2	M4-3	M5-1
CaO	0.022	0.022	0.011	0.009	0.013	0.026	0.012	0.009
MnO	0.008	0.008	0.006	0.000	0.006	0.006	0.008	0.000
FeO	0.007	0.007	0.008	0.005	0.008	0.007	0.000	0.000
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	34.788	34.811	34.766	34.764	34.833	34.821	34.777	34.812
P_2O_5	48.711	48.599	48.811	48.810	48.744	48.674	48.722	48.652
SiO_2	0.091	0.020	0.066	0.055	0.084	0.073	0.065	0.022
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.022	0.019	0.012	0.023	0.022	0.027	0.021	0.019
Na_2O	0.098	0.076	0.111	0.092	0.103	0.122	0.091	0.089
F	5.011	5.553	5.484	6.984	6.032	5.874	5.665	4.884
SrO	0.009	0.022	0.012	0.009	0.000	0.000	0.012	0.016
BaO	0.000	0.009	0.000	0.000	0.000	0.009	0.007	0.000
Li2O	10.184	10.165	10.184	10.191	10.187	10.160	10.181	10.174
H2O	3.802	3.532	3.582	2.869	3.322	3.391	3.490	3.853
subtotal	102.753	102.844	103.053	103.811	103.354	103.190	103.050	102.530
O=F	2.110	2.338	2.309	2.941	2.540	2.473	2.385	2.056
total	**100.643**	**100.506**	**100.744**	**100.870**	**100.814**	**100.717**	**100.665**	**100.474**
apfu								
Ca	0.001	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.995	0.998	0.994	0.994	0.996	0.996	0.995	0.997
P	1.001	1.001	1.002	1.002	1.001	1.001	1.002	1.001
Si	0.002	0.000	0.002	0.001	0.002	0.002	0.002	0.001
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001
Na	0.005	0.004	0.005	0.004	0.005	0.006	0.004	0.004
F	0.385	0.427	0.421	0.536	0.463	0.451	0.435	0.375
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Li	0.994	0.994	0.993	0.994	0.994	0.992	0.994	0.995
OH	0.615	0.573	0.579	0.464	0.537	0.549	0.565	0.625
v-site	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
x-site	0.997	0.998	0.995	0.995	0.998	0.998	0.997	0.998
y-site	1.001	1.001	1.002	1.002	1.001	1.001	1.002	1.001
z-site	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

montebrasite-amblygonite								
	M5-2	M5-3	M7-1	M7-2	M7-3	M8-1	M8-2	M8-3
CaO	0.014	0.017	0.000	0.008	0.009	0.012	0.023	0.019
MnO	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000
FeO	0.000	0.000	0.000	0.000	0.008	0.007	0.000	0.000
MgO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al_2O_3	34.784	34.764	34.674	34.585	34.633	34.588	34.612	34.558
P_2O_5	48.667	48.575	48.625	48.559	48.784	48.585	48.533	48.630
SiO_2	0.018	0.016	0.000	0.012	0.014	0.009	0.013	0.011
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K_2O	0.012	0.023	0.020	0.023	0.021	0.017	0.009	0.013
Na_2O	0.078	0.073	0.062	0.082	0.047	0.081	0.067	0.056
F	4.784	5.009	5.643	5.558	5.870	5.884	5.433	5.750
SrO	0.023	0.022	0.024	0.033	0.024	0.023	0.033	0.028
BaO	0.008	0.000	0.009	0.008	0.009	0.013	0.009	0.012
Li2O	10.177	10.161	10.165	10.133	10.187	10.139	10.143	10.155
H2O	3.900	3.785	3.480	3.511	3.384	3.358	3.570	3.424
subtotal	102.465	102.445	102.703	102.521	102.990	102.717	102.445	102.655
O=F	2.014	2.109	2.376	2.340	2.472	2.477	2.288	2.421
total	**100.451**	**100.336**	**100.327**	**100.181**	**100.518**	**100.239**	**100.157**	**100.234**
apfu								
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.997	0.997	0.995	0.994	0.992	0.994	0.995	0.993
P	1.002	1.001	1.003	1.003	1.004	1.003	1.002	1.004
Si	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.000
Na	0.004	0.003	0.003	0.004	0.002	0.004	0.003	0.003
F	0.368	0.386	0.435	0.429	0.451	0.454	0.419	0.443
Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Li	0.995	0.995	0.996	0.994	0.996	0.994	0.995	0.996
OH	0.632	0.614	0.565	0.571	0.549	0.546	0.581	0.557
v-site	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
x-site	0.997	0.998	0.995	0.995	0.993	0.994	0.996	0.993
y-site	1.002	1.001	1.003	1.003	1.004	1.003	1.002	1.004
z-site	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Microprobe analyses for all cassiterite samples.

Standards for EMP analyses for **Cassiterite** Acceleration potential: 15-20 kV Beam current: 15-22 nA Count times: 45 seconds per spot	
Cassiterite	Sn
Tantalite-(Mn), Himalaya Pegmatite CA	Ta
$YNbO_4$, synthetic	Nb
Clinopyroxene, “Cpx-26-ano”	Si
Clinopyroxene, “Cpx-26-ano”	Al
Rutile, synthetic	Ti
Tantalite-(Mn), Himalaya Pegmatite CA	Mn
Microlite Harding Pegmatite NM	Ca
Hematite, Elba, Italy	Fe
Other MAN standards used: Al_2O_3, synthetic Hematite, Elba MgO, synthetic PbO, synthetic V_2O_5, synthetic ZnO, synthetic ZrO_2, synthetic	

Cassiterite analyses were calculated based on 2 oxygen

	L2-1	L2-2	L2-3	L2-4	U-20-1	U-20-2	U-20-3	U-20-4
SnO_2	98.322	98.560	98.652	98.556	99.532	99.441	99.492	99.377
Ta_2O_5	0.892	0.672	0.723	0.744	0.234	0.188	0.109	0.125
Nb_2O_5	0.023	0.031	0.028	0.015	0.011	0.000	0.000	0.013
SiO_2	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.022
Al_2O_3	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.000
TiO_2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MnO	0.010	0.022	0.008	0.008	0.033	0.014	0.009	0.012
CaO	0.000	0.000	0.000	0.000	0.009	0.011	0.008	0.000
FeO	0.012	0.030	0.009	0.012	0.102	0.088	0.093	0.017
Total	99.259	99.315	99.442	99.335	99.933	99.742	99.711	99.566
apfu								
Sn	0.992	0.993	0.993	0.993	0.996	0.997	0.998	0.998
Ta	0.003	0.002	0.002	0.003	0.001	0.001	0.000	0.000
Nb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Si	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Al	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.000	0.001	0.000	0.000	0.002	0.002	0.002	0.000

	U-20-5	U-20-6	L2-1-1	L2-1-2	L2-1-3
SnO_2	99.281	99.612	98.923	99.133	99.254
Ta_2O_5	0.141	0.091	0.245	0.312	0.333
Nb_2O_5	0.000	0.000	0.121	0.091	0.089
SiO_2	0.025	0.022	0.000	0.000	0.000
Al_2O_3	0.000	0.000	0.000	0.000	0.000
TiO_2	0.000	0.000	0.009	0.000	0.000
MnO	0.044	0.021	0.023	0.030	0.034
CaO	0.000	0.008	0.000	0.000	0.000
FeO	0.033	0.043	0.078	0.026	0.055
Total	99.524	99.797	99.399	99.592	99.765
apfu					
Sn	0.997	0.998	0.995	0.995	0.995
Ta	0.000	0.000	0.001	0.001	0.001
Nb	0.000	0.000	0.001	0.001	0.001
Si	0.001	0.001	0.000	0.000	0.000
Al	0.000	0.000	0.000	0.000	0.000
Ti	0.000	0.000	0.000	0.000	0.000
Mn	0.001	0.000	0.000	0.001	0.001
Ca	0.000	0.000	0.000	0.000	0.000
Fe	0.001	0.001	0.002	0.001	0.001

	L2-6-1	L2-6-2	L3-1/2-14-1	L3-1/2-14-2	L3-1/2-14-3
SnO_2	99.345	99.315	99.445	99.669	99.534
Ta_2O_5	0.234	0.315			
Nb_2O_5	0.101	0.078			
SiO_2	0.000	0.000	0.000	0.055	0.023
Al_2O_3	0.000	0.000	0.000	0.011	0.009
TiO_2	0.000	0.000	0.000	0.000	0.000
MnO	0.036	0.055	0.033	0.042	0.031
CaO	0.000	0.000	0.000	0.009	0.000
FeO	0.022	0.054	0.055	0.100	0.055
Total	99.738	99.817	99.533	99.886	99.652
apfu					
Sn	0.996	0.995	0.999	0.997	0.998
Ta	0.001	0.001	0.000	0.000	0.000
Nb	0.001	0.000	0.000	0.000	0.000
Si	0.000	0.000	0.000	0.001	0.001
Al	0.000	0.000	0.000	0.000	0.000
Ti	0.000	0.000	0.000	0.000	0.000
Mn	0.001	0.001	0.001	0.001	0.001
Ca	0.000	0.000	0.000	0.000	0.000
Fe	0.000	0.001	0.001	0.002	0.001

Vita

Leah Rae Grassi was born in Madrid, Spain and moved to San Antonio, TX in 1986. In 1992, she moved with her family to Miami, FL there, she completed high school at Miami Sunset Senior High School, June 2002. After moving to New Orleans, LA she entered the University of New Orleans in 2008. She received her Bachelor of Science in Earth and Environmental Science May of 2012. She began graduate work at the University of New Orleans the following August.

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